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Liang et al.

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(54) **OAM SYSTEM FOR LTE-U AND WI-FI OPERATION AND COEXISTENCE DEPLOYMENT**

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(22) Filed: **Apr. 3, 2015**

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(51) **Int. Cl.**
H04W 4/00 (2009.01)
H04M 3/22 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04M 3/2263*** (2013.01); ***H04W 16/14*** (2013.01); ***H04W 24/02*** (2013.01); *H04W 72/0426* (2013.01); *H04W 72/0453* (2013.01); *H04W 88/08* (2013.01)

(58) **Field of Classification Search**
CPC ... H04W 16/14; H04W 16/16; H04W 16/18; H04W 24/02; H04W 24/04; H04W 24/10; H04W 84/12; H04W 84/14; H04W 84/16
USPC 455/414.1, 418, 419, 420, 432, 435.2, 455/435.3, 436, 444, 446, 447, 448, 449, 455/452.2, 552.1
See application file for complete search history.

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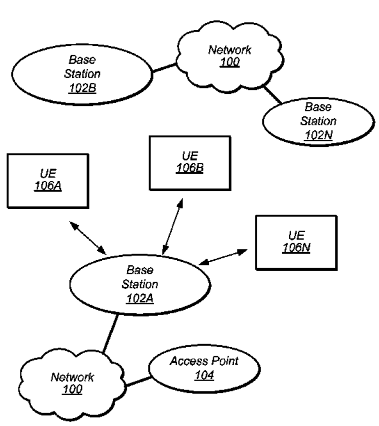
(57) **ABSTRACT**

This disclosure relates to operation and management of cellular communication systems including cells and access points operating in unlicensed frequency bands. According to some embodiments, a base station in a network may receive operation and management policy information, including information for configuring network elements operating in unlicensed frequency bands. The policy information may include information for coordinating network elements operating in unlicensed frequency bands in a manner configured to reduce interference in the unlicensed frequency bands. The base station may provide configuration information to one or more network elements in the network operating in unlicensed frequency bands. The configured network elements may operate in the unlicensed frequency bands in accordance with the configuration information.

17 Claims, 16 Drawing Sheets



(51) **Int. Cl.**

H04W 16/14	(2009.01)
H04W 24/02	(2009.01)
H04W 88/08	(2009.01)
H04W 72/04	(2009.01)

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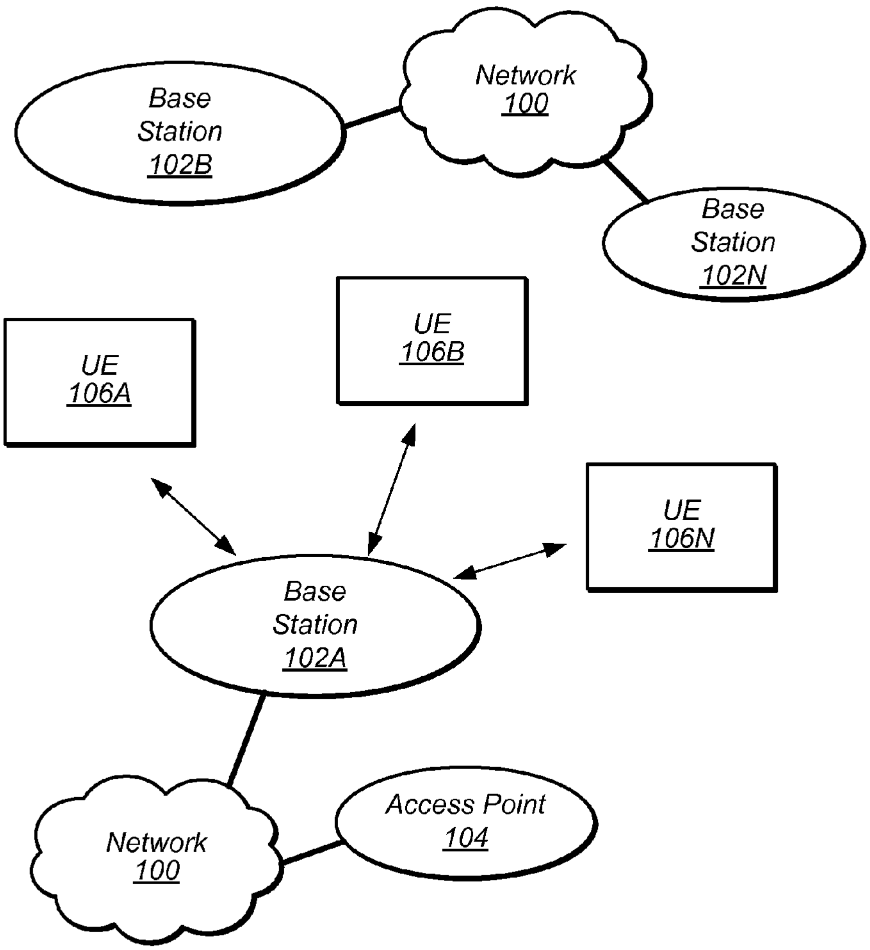

Base Station 102B
Network 100
Base Station 102N
UE 106A
UE 106B
UE 106N
Base Station 102A
Network 100
Access Point 104

FIG. 1

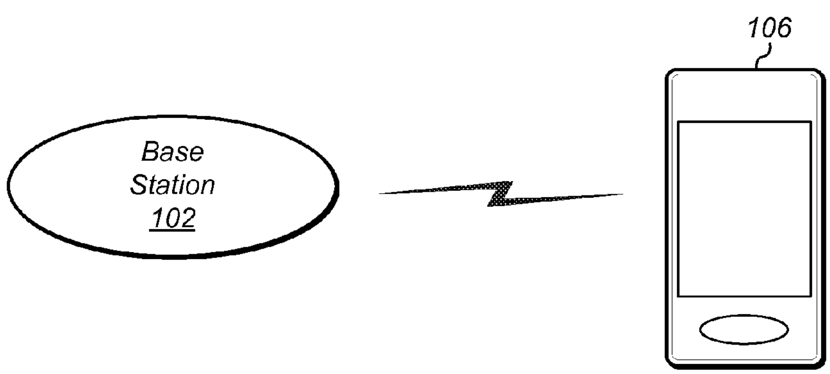

106
Base Station 102

FIG. 2

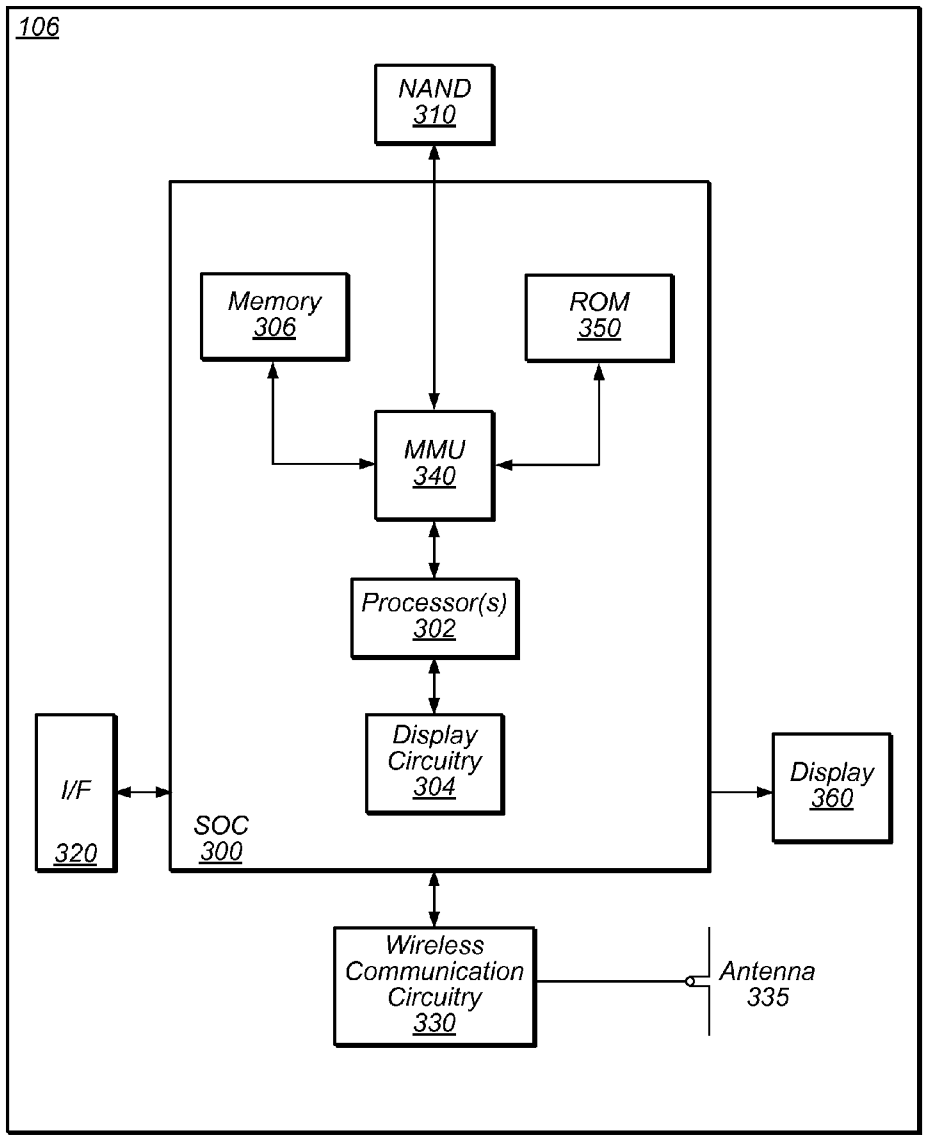

106
NAND
310
Memory
306
ROM
350
MMU
340
Processor(s)
302
Display
Circuitry
304
I/F
320
SOC
300
Display
360
Wireless
Communication
Circuitry
330
Antenna
335

FIG. 3

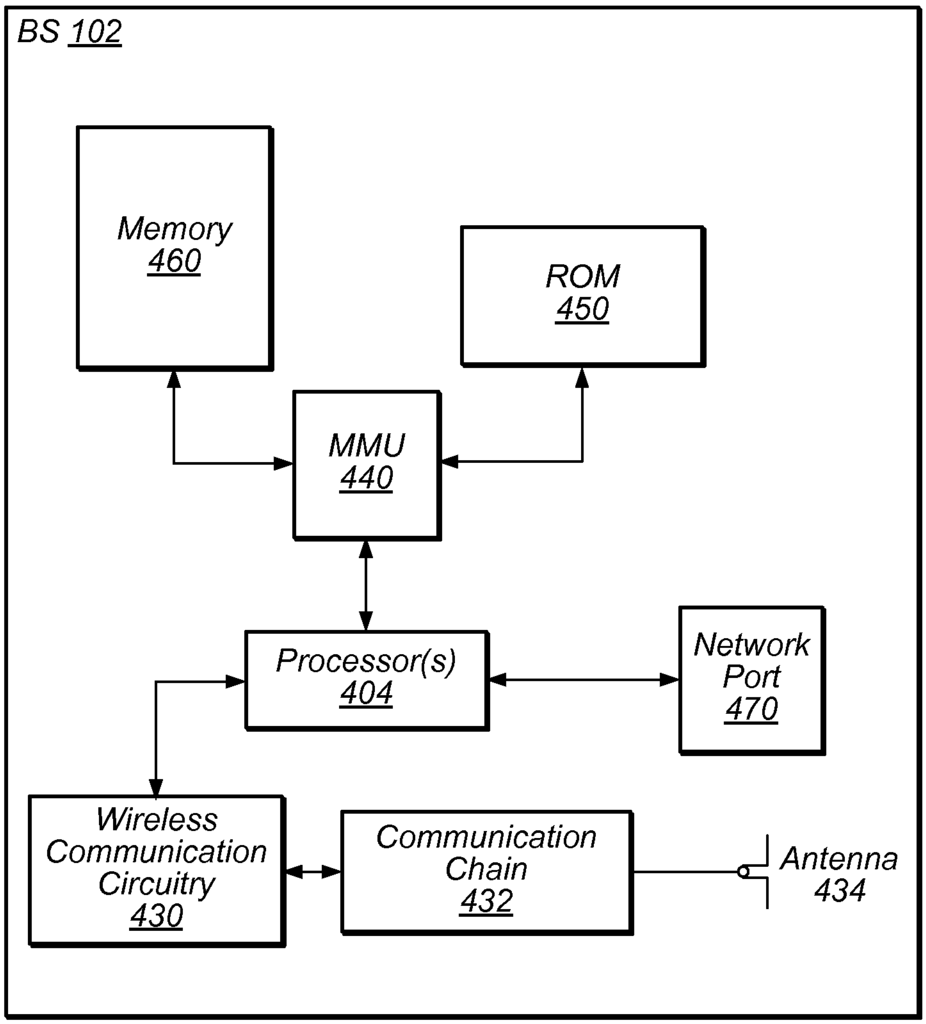

BS 102
Memory
460
ROM
450
MMU
440
Processor(s)
404
Network
Port
470
Wireless
Communication
Circuitry
430
Communication
Chain
432
Antenna
434

FIG. 4

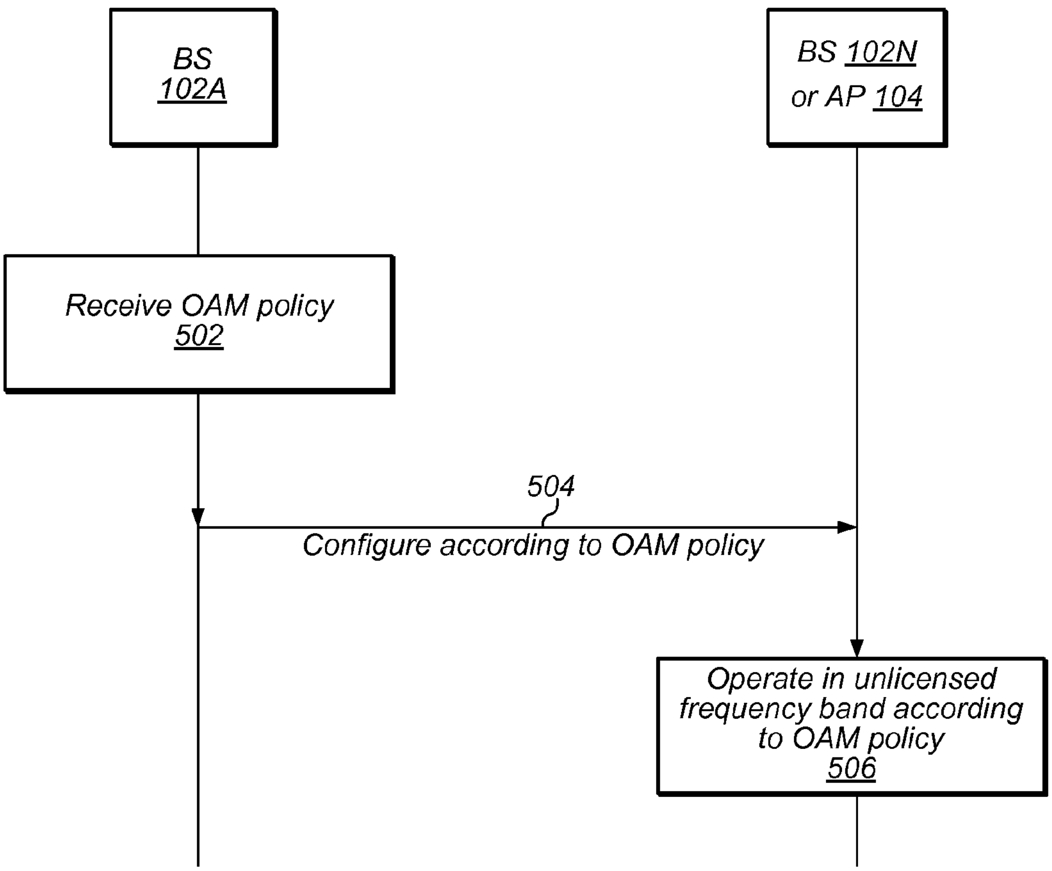

BS
102A
BS 102N
or AP 104
Receive OAM policy
502
504
Configure according to OAM policy
Operate in unlicensed frequency band according to OAM policy
506

FIG. 5

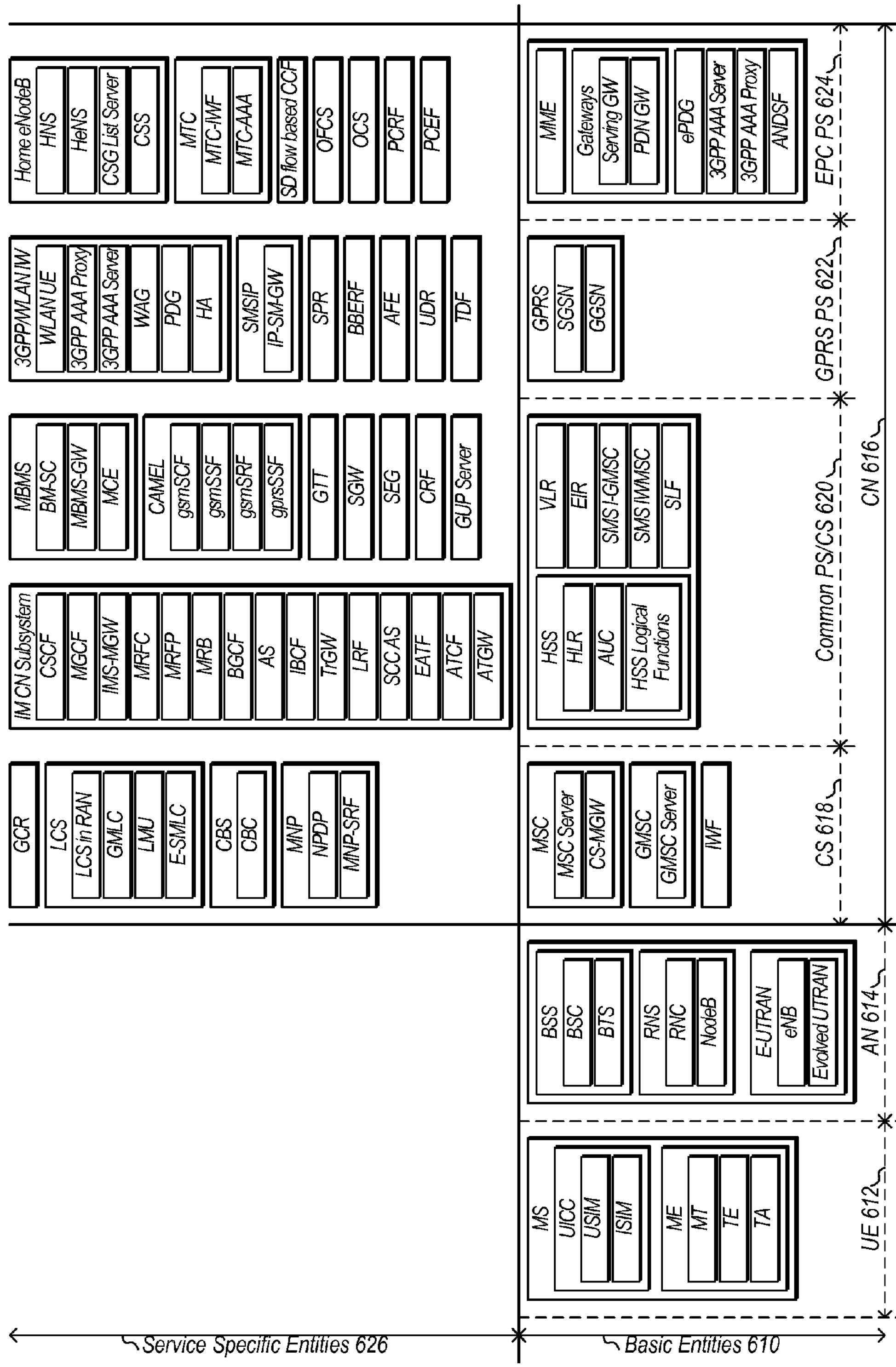
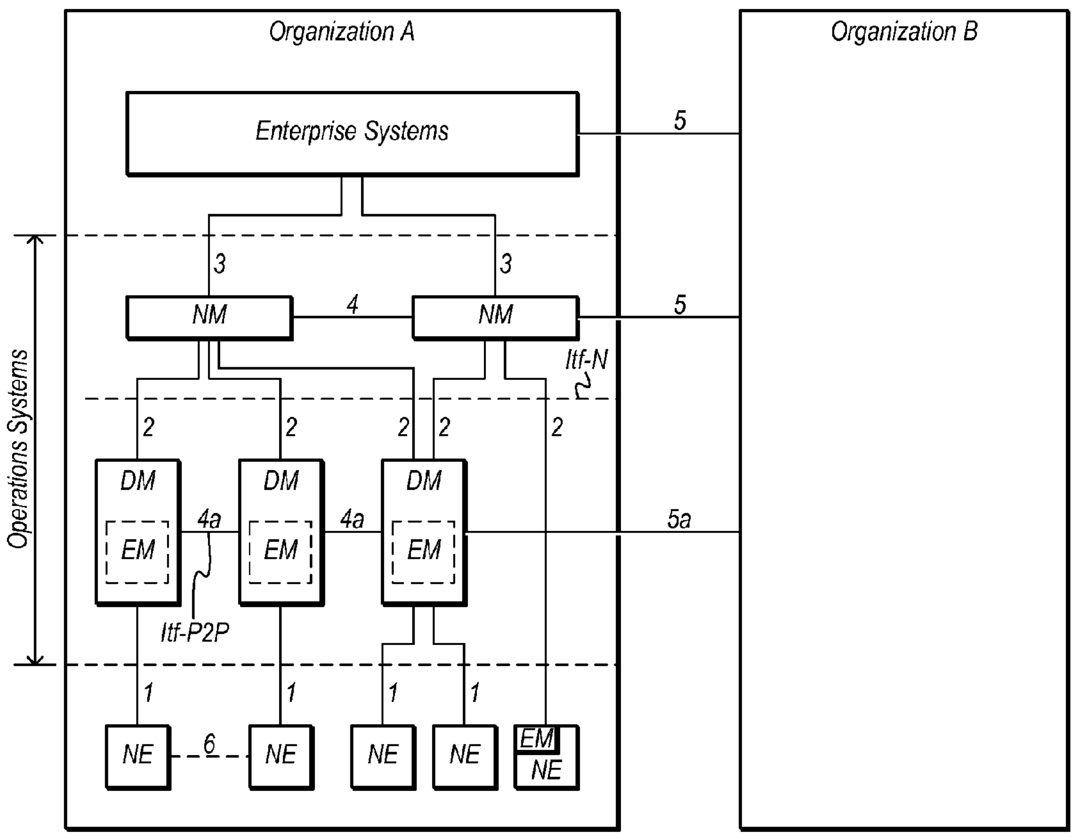
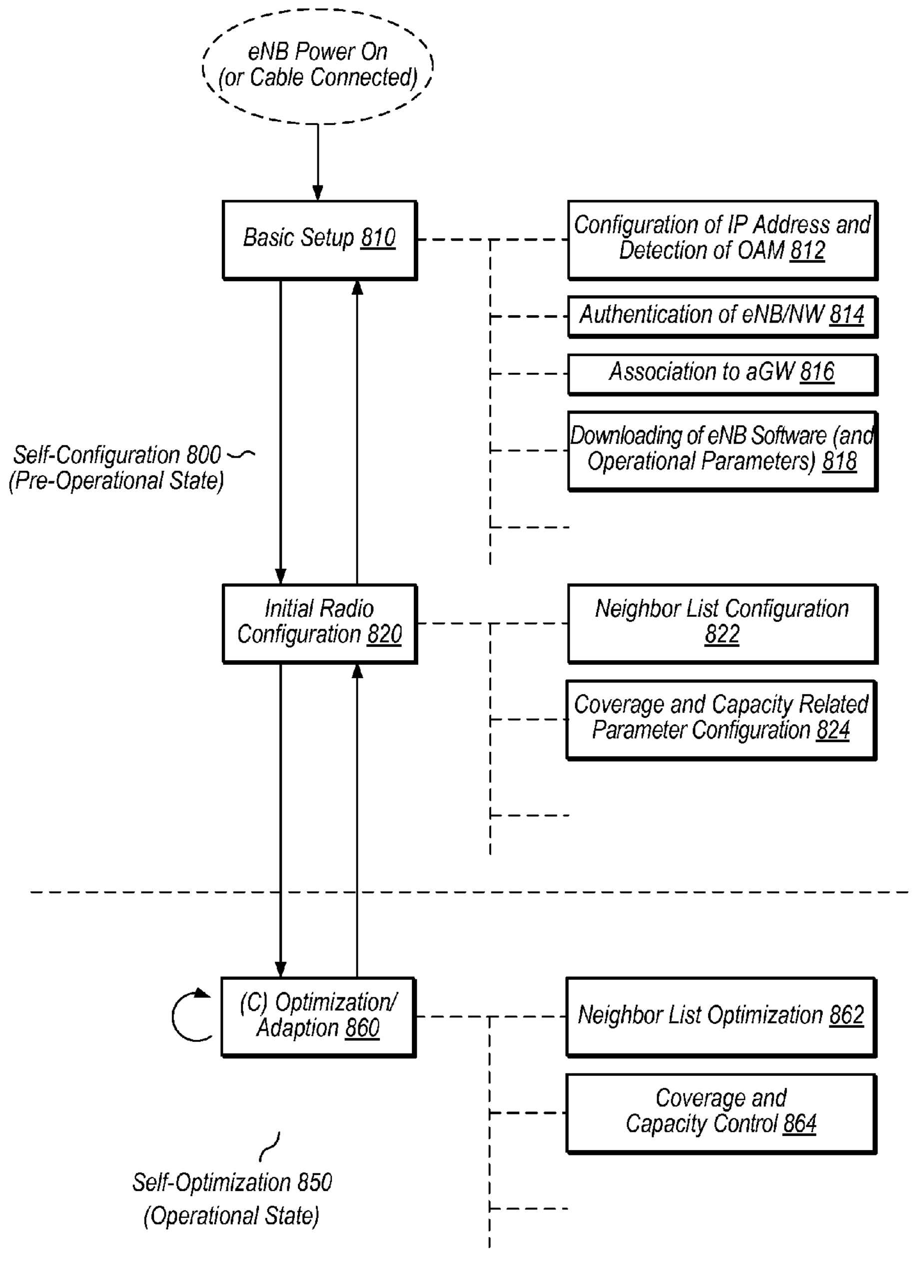

Home eNodeB
HNS
HeNS
CSG List Server
CSS
MTC
MTC-IWF
MTC-AAA
SD flow based CCF
OFCS
OCS
PCRF
PCEF
3GPP/WLAN IW
WLAN UE
3GPP AAA Proxy
3GPP AAA Server
WAG
PDG
HA
SMSIP
IP-SM-GW
SPR
BBERF
AFE
UDR
TDF
MBMS
BM-SC
MBMS-GW
MCE
CAMEL
gsmSCF
gsmSSF
gsmSRF
gprsSSF
GTT
SGW
SEG
CRF
GUP Server
IM CN Subsystem
CSCF
MGCF
IMS-MGW
MRFC
MRFP
MRB
BGCF
AS
IBCF
TrGW
LRF
SCC AS
EATF
ATCF
ATGW
GCR
LCS
LCS in RAN
GMLC
LMU
E-SMLC
CBS
CBC
MNP
NPDP
MNP-SRF
MME
Gateways
Serving GW
PDN GW
ePDG
3GPP AAA Server
3GPP AAA Proxy
ANDSF
EPC PS 624
GPRS
SGSN
GGSN
GPRS PS 622
VLR
EIR
SMS I-GMSC
SMS IWMSC
SLF
HSS
HLR
AUC
HSS Logical Functions
Common PS/CS 620
CN 616
MSC
MSC Server
CS-MGW
GMSC
GMSC Server
IWF
CS 618
BSS
BSC
BTS
RNS
RNC
NodeB
E-UTRAN
eNB
Evolved UTRAN
AN 614
MS
UICC
USIM
ISIM
ME
MT
TE
TA
UE 612
Service Specific Entities 626
Basic Entities 610

FIG. 6



Organization A
Organization B
Enterprise Systems
5
3
3
NM
4
NM
5
Itf-N
Operations Systems
2
2
2
2
2
DM
EM
4a
DM
EM
4a
DM
EM
5a
Itf-P2P
1
1
1
1
NE
6
NE
NE
NE
EM
NE

FIG. 7



eNB Power On
(or Cable Connected)
Basic Setup 810
Configuration of IP Address and Detection of OAM 812
Authentication of eNB/NW 814
Association to aGW 816
Downloading of eNB Software (and Operational Parameters) 818
Self-Configuration 800
(Pre-Operational State)
Initial Radio Configuration 820
Neighbor List Configuration 822
Coverage and Capacity Related Parameter Configuration 824
(C) Optimization/ Adaption 860
Neighbor List Optimization 862
Coverage and Capacity Control 864
Self-Optimization 850
(Operational State)

FIG. 8

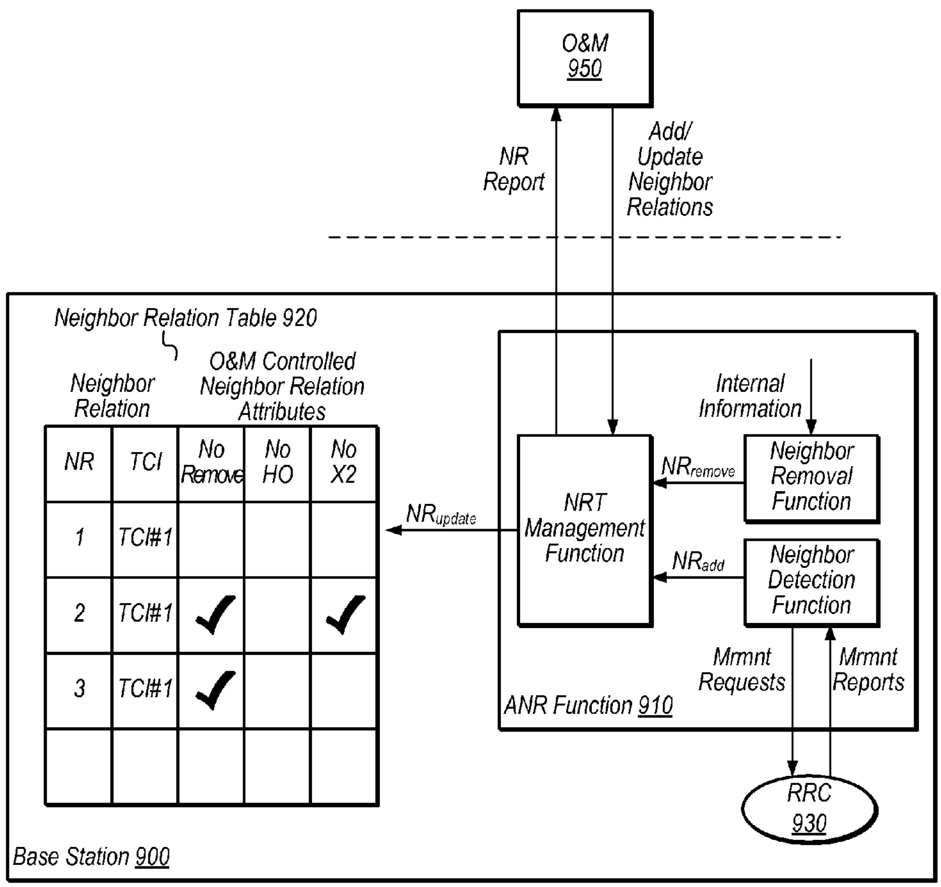

O&M
950
NR
Report
Add/
Update
Neighbor
Relations
Neighbor Relation Table 920
Neighbor
Relation
O&M Controlled
Neighbor Relation
Attributes
NR
TCI
No
Remove
No
HO
No
X2
1
TCI#1
2
TCI#1
3
TCI#1
NRupdate
NRT
Management
Function
Internal
Information
NRremove
Neighbor
Removal
Function
NRadd
Neighbor
Detection
Function
Mrmnt
Requests
Mrmnt
Reports
ANR Function 910
RRC
930
Base Station 900

FIG. 9

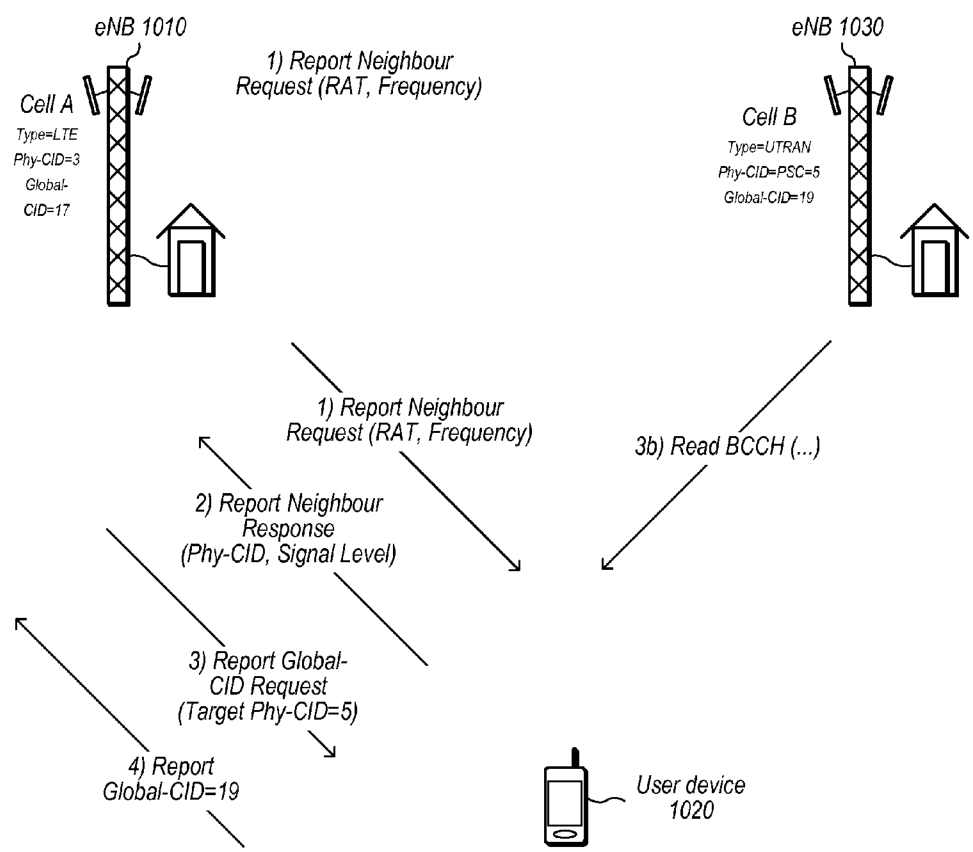

eNB 1010
1) Report Neighbour Request (RAT, Frequency)
eNB 1030
Cell A
Type=LTE
Phy-CID=3
Global-CID=17
Cell B
Type=UTRAN
Phy-CID=PSC=5
Global-CID=19
1) Report Neighbour Request (RAT, Frequency)
3b) Read BCCH (...)
2) Report Neighbour Response (Phy-CID, Signal Level)
3) Report Global-CID Request (Target Phy-CID=5)
4) Report Global-CID=19
User device 1020

FIG. 10

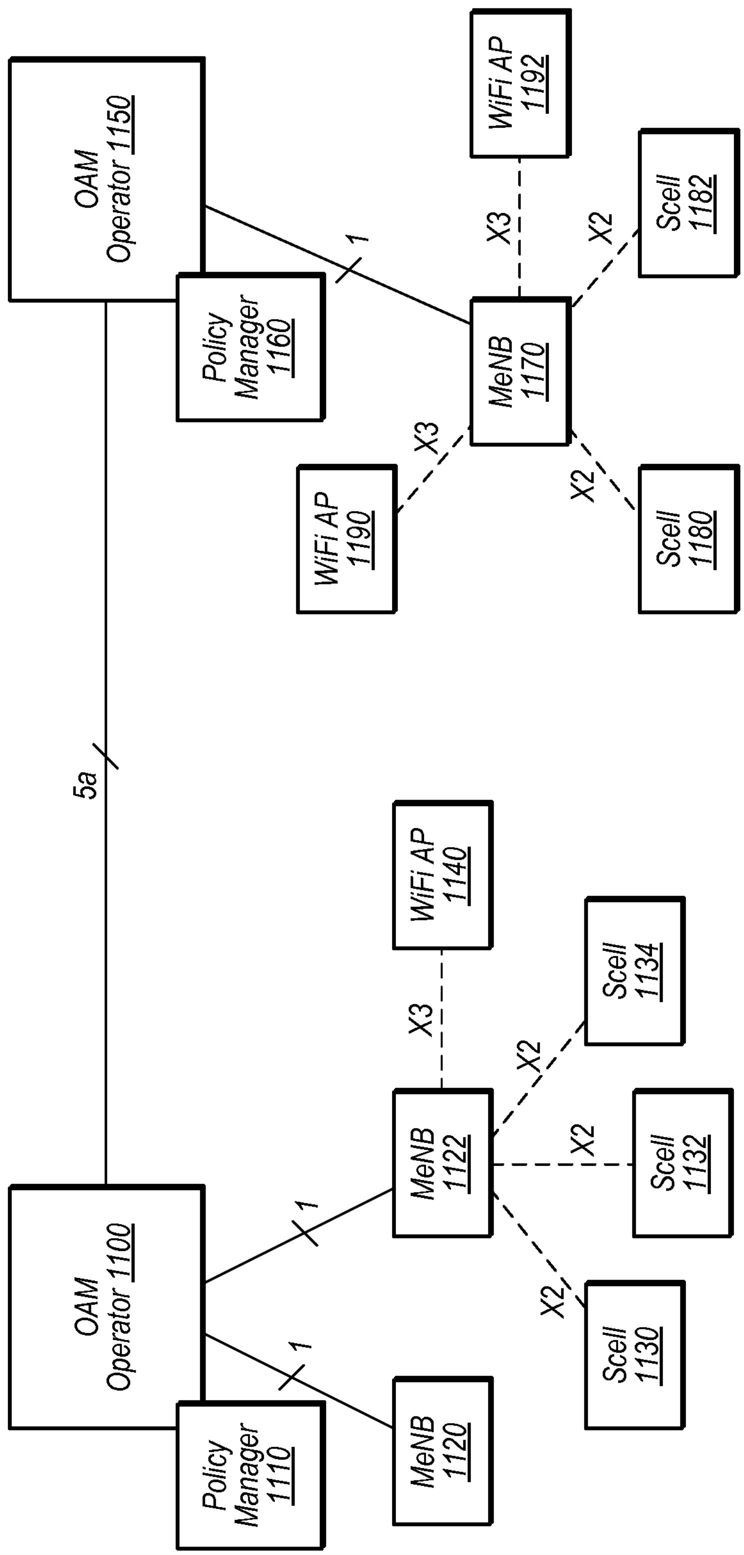

OAM Operator 1150
Policy Manager 1160
1
MeNB 1170
WiFi AP 1192
X3
Scell 1182
X2
X3
WiFi AP 1190
X2
Scell 1180
5a
OAM Operator 1100
Policy Manager 1110
1
MeNB 1122
1
MeNB 1120
X3
WiFi AP 1140
X2
Scell 1134
X2
Scell 1132
X2
Scell 1130

FIG. 11

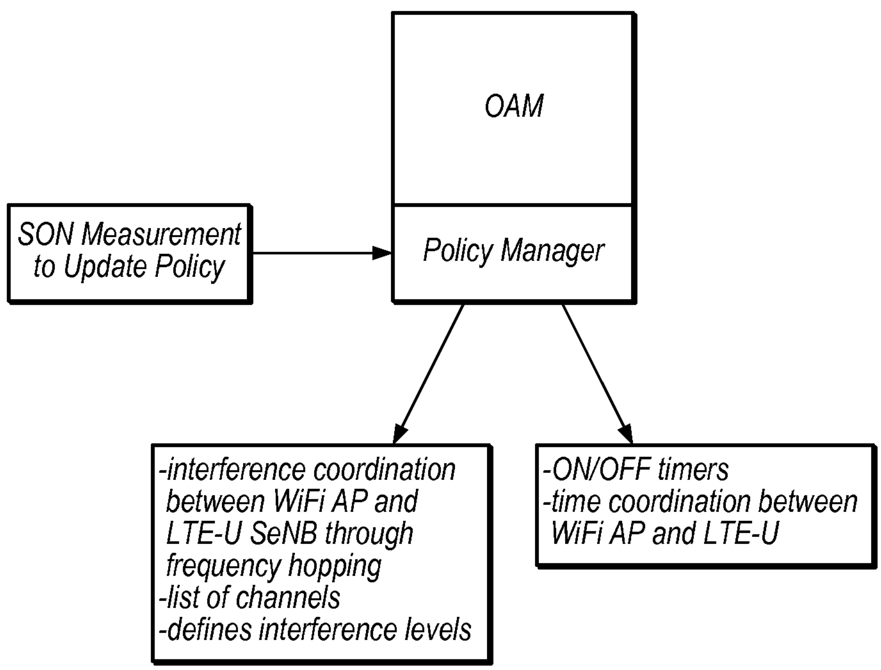

OAM
Policy Manager
SON Measurement to Update Policy
-interference coordination between WiFi AP and LTE-U SeNB through frequency hopping
-list of channels
-defines interference levels
-ON/OFF timers
-time coordination between WiFi AP and LTE-U

FIG. 12

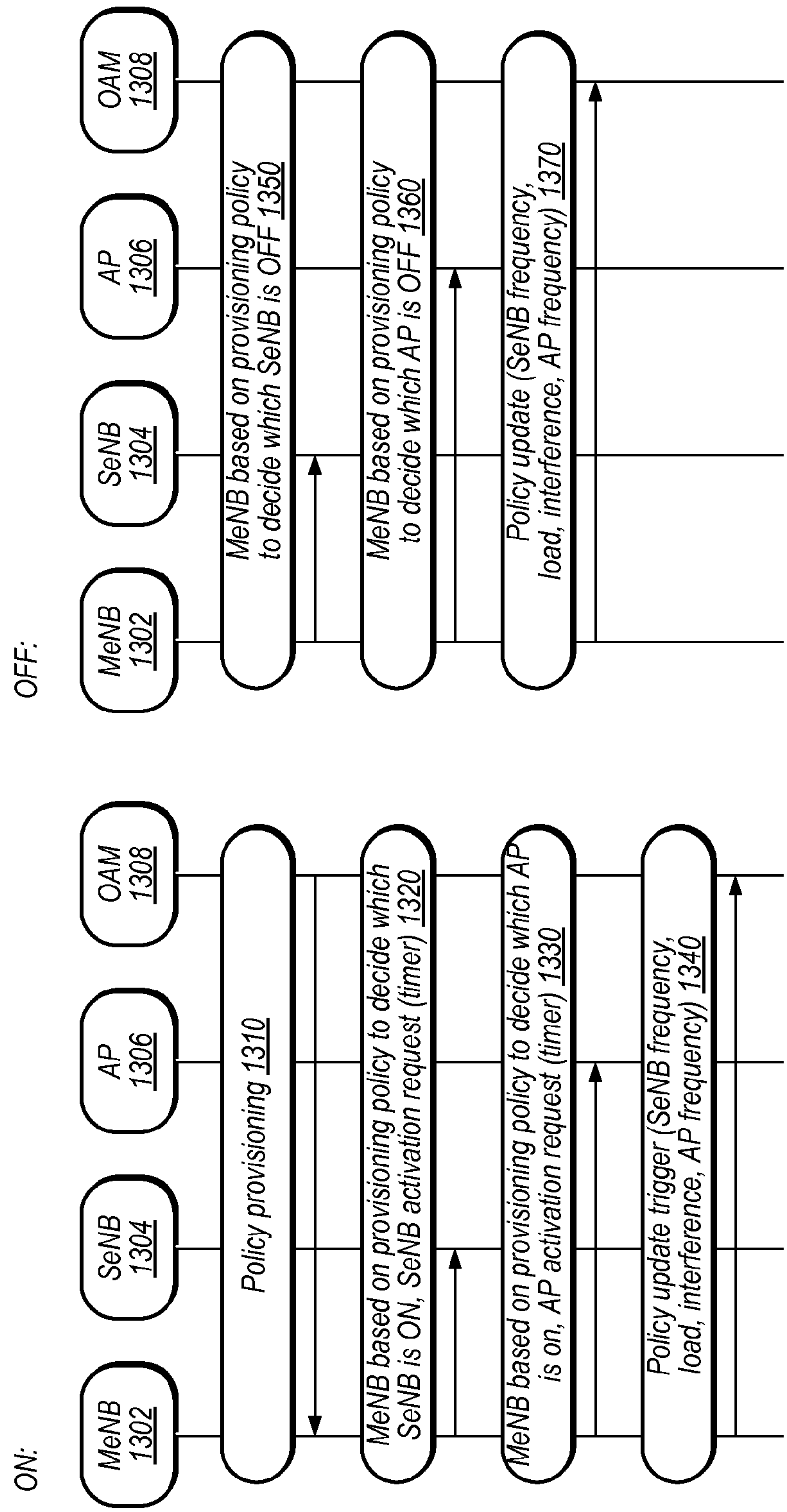

ON:
MeNB 1302
SeNB 1304
AP 1306
OAM 1308
Policy provisioning 1310
MeNB based on provisioning policy to decide which SeNB is ON, SeNB activation request (timer) 1320
MeNB based on provisioning policy to decide which AP is on, AP activation request (timer) 1330
Policy update trigger (SeNB frequency, load, interference, AP frequency) 1340
OFF:
MeNB 1302
SeNB 1304
AP 1306
OAM 1308
MeNB based on provisioning policy to decide which SeNB is OFF 1350
MeNB based on provisioning policy to decide which AP is OFF 1360
Policy update (SeNB frequency, load, interference, AP frequency) 1370

FIG. 13

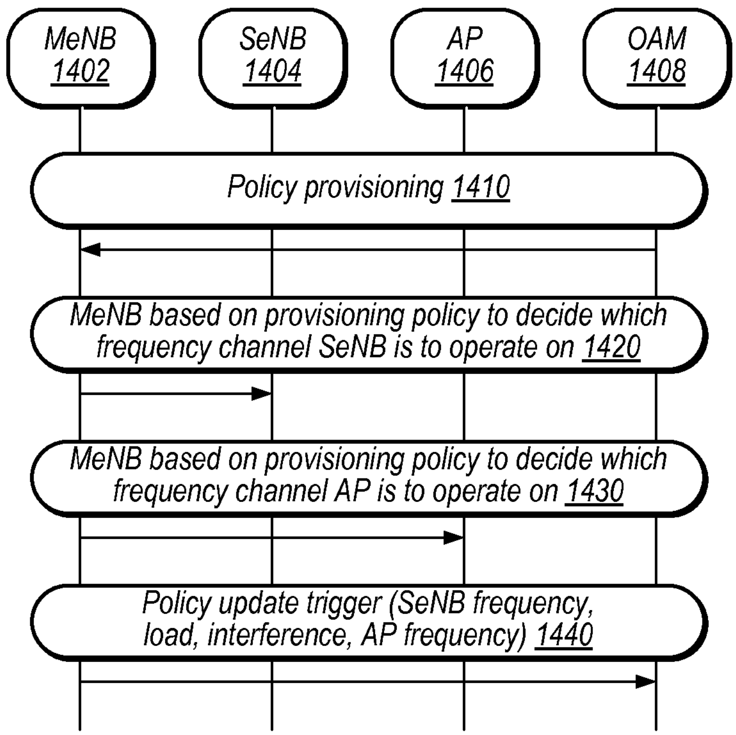

MeNB
1402
SeNB
1404
AP
1406
OAM
1408
Policy provisioning 1410
MeNB based on provisioning policy to decide which frequency channel SeNB is to operate on 1420
MeNB based on provisioning policy to decide which frequency channel AP is to operate on 1430
Policy update trigger (SeNB frequency, load, interference, AP frequency) 1440

FIG. 14

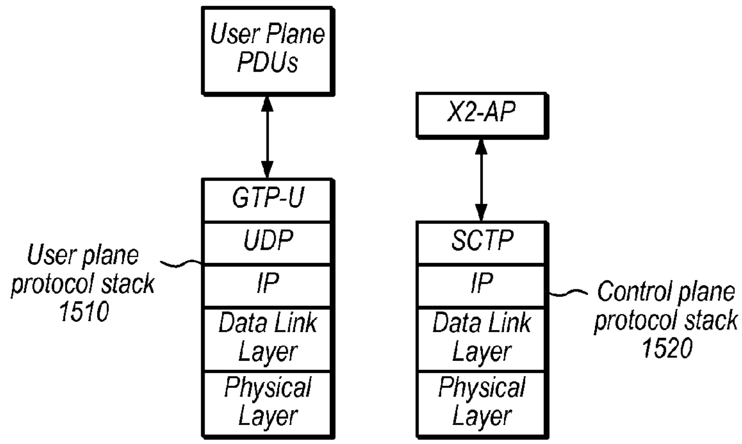


FIG. 15

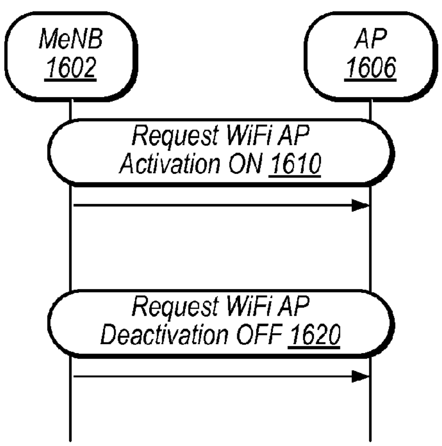


FIG. 16

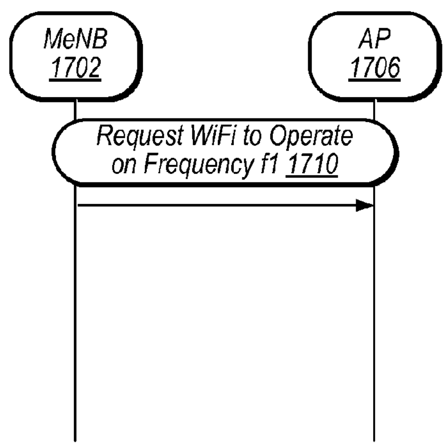
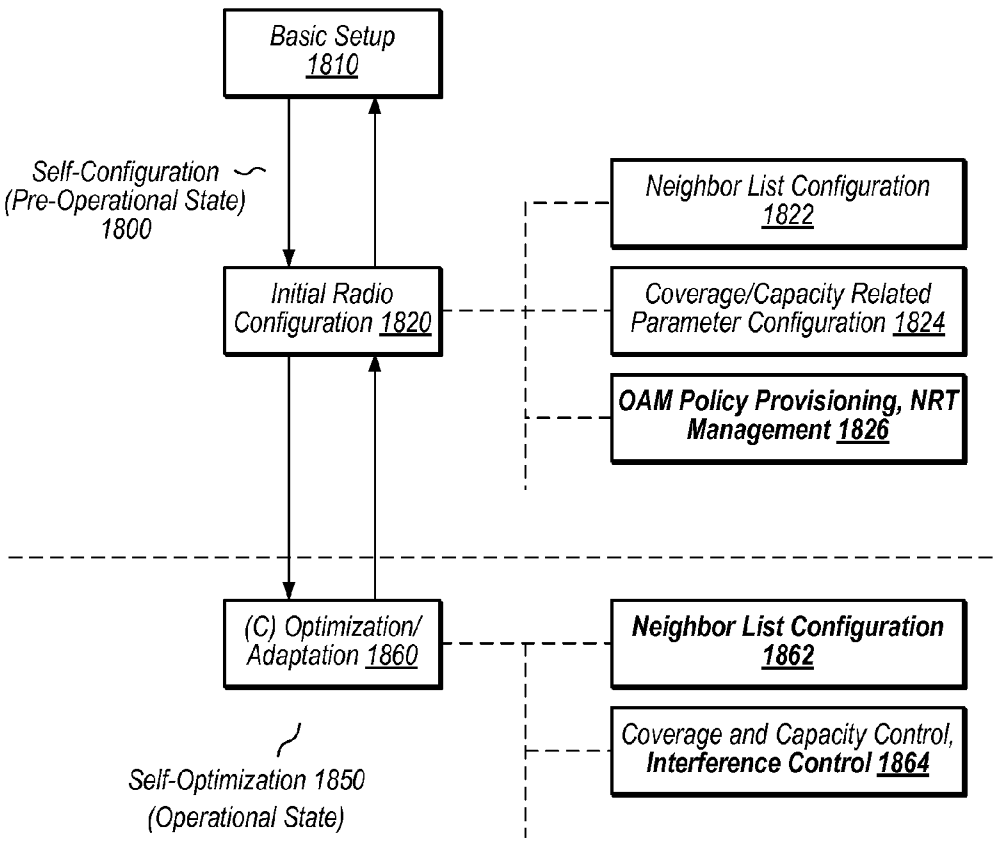


FIG. 17



Basic Setup 1810
Self-Configuration (Pre-Operational State) 1800
Initial Radio Configuration 1820
Neighbor List Configuration 1822
Coverage/Capacity Related Parameter Configuration 1824
OAM Policy Provisioning, NRT Management 1826
(C) Optimization/ Adaptation 1860
Neighbor List Configuration 1862
Coverage and Capacity Control, Interference Control 1864
Self-Optimization 1850 (Operational State)

FIG. 18

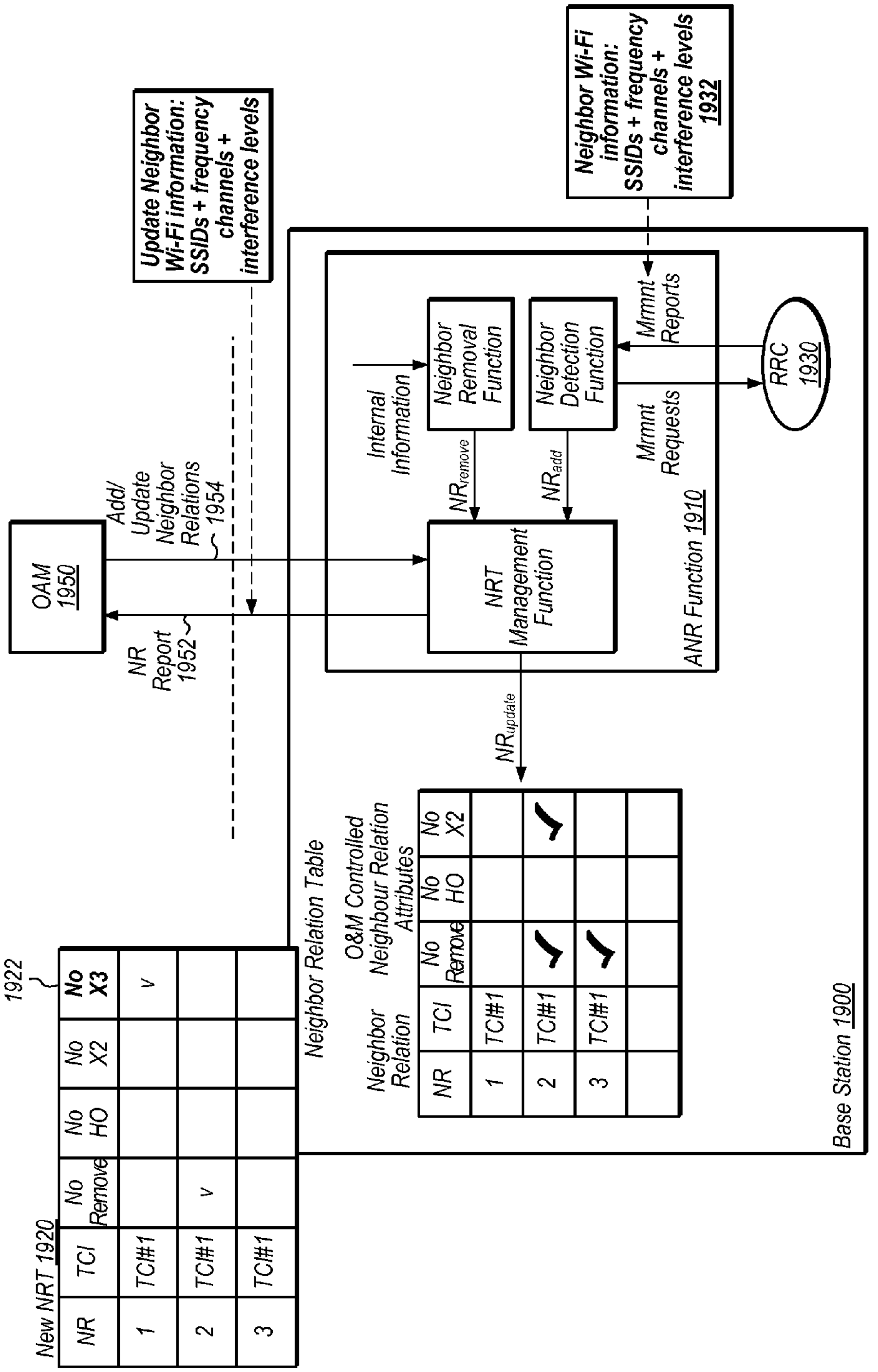

Update Neighbor Wi-Fi information: SSIDs + frequency channels + interference levels
Neighbor Wi-Fi information: SSIDs + frequency channels + interference levels
1932
OAM
1950
Add/ Update Neighbor Relations
1954
NR Report
1952
NRT Management Function
Neighbor Removal Function
Neighbor Detection Function
Internal Information
NR_{remove}
NR_{add}
Mrmnt Reports
Mrmnt Requests
RRC
1930
ANR Function 1910
NR_{update}
Neighbor Relation Table
Neighbor Relation
O&M Controlled Neighbour Relation Attributes
NR
TCI
No Remove
No HO
No X2
TCI#1
Base Station 1900
New NRT 1920
1922
No X3

FIG. 19

OAM SYSTEM FOR LTE-U AND WI-FI OPERATION AND COEXISTENCE DEPLOYMENT

PRIORITY CLAIM

The present application claims benefit of priority to U.S. Provisional Application No. 61/975,096 titled "OAM System for LTE-U and Wi-Fi Operation and Coexistence Deployment" and filed on Apr. 4, 2014, which is hereby incorporated by reference in its entirety as though fully and completely set forth herein.

FIELD

The present application relates to wireless communications, including managing cellular network elements that operate in unlicensed frequency bands.

DESCRIPTION OF THE RELATED ART

Wireless communication systems are rapidly growing in usage. Additionally, there exist numerous different wireless communication technologies and standards. Some examples of wireless communication standards include GSM, UMTS (associated with, for example, WCDMA or TD-SCDMA air interfaces), LTE, LTE Advanced (LTE-A), HSPA, 3GPP2 CDMA2000 (e.g., 1×RTT, 1×EV-DO, HRPD, eHRPD), IEEE 802.11 (WLAN or Wi-Fi), IEEE 802.16 (WiMAX), Bluetooth, and others.

In some wireless communication systems, such as certain cellular communication networks, wireless communication is performed on frequency bands that have been licensed (e.g., by a cellular network provider). Additionally, in some wireless communication systems, such as Wi-Fi and Bluetooth wireless communication systems, wireless communication is performed on unlicensed frequency bands, such as the 2.4 GHz ISM frequency band.

SUMMARY

Embodiments are presented herein of apparatuses, systems, and methods for managing cellular network elements that operate in unlicensed frequency bands.

The techniques provided herein may, according to some embodiments, reduce the occurrence and/or severity of interference between network elements operating in unlicensed frequency bands, potentially including between network elements operating as part of different networks and/or between network elements operating according to different wireless communication technologies.

According to some embodiments, certain network elements in a network may receive operation and management policy information, which may include information for configuring other network elements in the network, including those operating in unlicensed frequency bands. The operation and management policy information may, for example, specify how to configure network elements operating in unlicensed frequency bands depending on certain current characteristics of wireless communication systems in the vicinity. Those network elements enforcing the operation and management policy may accordingly measure the relevant parameters and characteristics and configure any network elements for which they are responsible in accordance with the operation and management policy based on the current system parameters.

For example, a base station, which receives operation and management policy information and is tasked with applying the operation and management policy, might acquire (e.g., from user devices served by the base station and/or from other network elements) information regarding nearby network elements, including any or all of identification information, operation frequency information, interference information, type(s) of wireless communication used, network affiliation, and/or any other information. The base station might then determine how to configure any network elements managed by the base station that are configured to operate in unlicensed frequency bands in accordance with the operation and management policy, in view of its knowledge of nearby network elements and their characteristics.

The base station may then, according to some embodiments, provide configuration information to such network elements. The configuration information may include information indicating when to operate and/or at which frequency or frequencies to operate, among various possible information. The times and/or frequencies may be selected, in accordance with the operation and management policy, in a coordinated manner with any other known nearby network elements, such that interference between network elements in unlicensed frequency bands is minimized.

The techniques described herein may be implemented in and/or used with a number of different types of devices, including but not limited to cellular base stations, cellular phones, tablet computers, wearable computing devices, portable media players, and any of various other computing devices.

This Summary is intended to provide a brief overview of some of the subject matter described in this document. Accordingly, it will be appreciated that the above-described features are merely examples and should not be construed to narrow the scope or spirit of the subject matter described herein in any way. Other features, aspects, and advantages of the subject matter described herein will become apparent from the following Detailed Description, Figures, and Claims.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the present subject matter can be obtained when the following detailed description of the embodiments is considered in conjunction with the following drawings, in which:

FIG. **1** illustrates an exemplary (and simplified) wireless communication system, according to some embodiments;

FIG. **2** illustrates an exemplary (and simplified) base station (BS) in communication with a user equipment (UE) device, according to some embodiments;

FIG. **3** illustrates an exemplary block diagram of a UE, according to some embodiments;

FIG. **4** illustrates an exemplary block diagram of a BS, according to some embodiments;

FIG. **5** is a communication flow diagram illustrating an exemplary method for managing network elements operating in unlicensed frequency bands, according to some embodiments;

FIGS. **6-7** illustrate exemplary OAM interfaces and entities with which an OAM may interface;

FIGS. **8-10** illustrate exemplary aspects of possible SON functionality in a cellular network, according to some embodiments;

FIG. **11** illustrates an exemplary OAM architecture for managing network elements operating in unlicensed frequency bands, according to some embodiments;

FIG. **12** illustrates an exemplary OAM Policy Manager configured to manage network elements operating in unlicensed frequency bands, according to some embodiments;

FIGS. **13-14** illustrate exemplary OAM communication flows for on/off and frequency hopping respectively, according to some embodiments;

FIGS. **15-17** illustrate exemplary aspects of an X3 interface, according to some embodiments; and

FIG. **18-19** illustrate exemplary aspects of possible SON functionality configured for use in conjunction with managing cellular network elements operating in unlicensed frequency bands, according to some embodiments.

While the features described herein may be susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and are herein described in detail. It should be understood, however, that the drawings and detailed description thereto are not intended to be limiting to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the subject matter as defined by the appended claims.

DETAILED DESCRIPTION

Terms

The following is a glossary of terms used in this disclosure:

Memory Medium—Any of various types of non-transitory memory devices or storage devices. The term "memory medium" is intended to include an installation medium, e.g., a CD-ROM, floppy disks, or tape device; a computer system memory or random access memory such as DRAM, DDR RAM, SRAM, EDO RAM, Rambus RAM, etc.; a non-volatile memory such as a Flash, magnetic media, e.g., a hard drive, or optical storage; registers, or other similar types of memory elements, etc. The memory medium may include other types of non-transitory memory as well or combinations thereof. In addition, the memory medium may be located in a first computer system in which the programs are executed, or may be located in a second different computer system which connects to the first computer system over a network, such as the Internet. In the latter instance, the second computer system may provide program instructions to the first computer for execution. The term "memory medium" may include two or more memory mediums which may reside in different locations, e.g., in different computer systems that are connected over a network. The memory medium may store program instructions (e.g., embodied as computer programs) that may be executed by one or more processors.

Carrier Medium—a memory medium as described above, as well as a physical transmission medium, such as a bus, network, and/or other physical transmission medium that conveys signals such as electrical, electromagnetic, or digital signals.

Programmable Hardware Element—includes various hardware devices comprising multiple programmable function blocks connected via a programmable interconnect. Examples include FPGAs (Field Programmable Gate Arrays), PLDs (Programmable Logic Devices), FPOAs (Field Programmable Object Arrays), and CPLDs (Complex PLDs). The programmable function blocks may range from fine grained (combinatorial logic or look up tables) to coarse grained (arithmetic logic units or processor cores). A programmable hardware element may also be referred to as "reconfigurable logic".

Computer System—any of various types of computing or processing systems, including a personal computer system (PC), mainframe computer system, workstation, network appliance, Internet appliance, personal digital assistant (PDA), television system, grid computing system, or other device or combinations of devices. In general, the term "computer system" can be broadly defined to encompass any device (or combination of devices) having at least one processor that executes instructions from a memory medium.

User Equipment (UE) (or "UE Device")—any of various types of computer systems devices which are mobile or portable and which performs wireless communications. Examples of UE devices include mobile telephones or smart phones (e.g., iPhone™, Android™-based phones), portable gaming devices (e.g., Nintendo DS™, PlayStation Portable™, Gameboy Advance™, iPhone™), wearable devices (e.g., smart watch, smart glasses), laptops, PDAs, portable Internet devices, music players, data storage devices, or other handheld devices, etc. In general, the term "UE" or "UE device" can be broadly defined to encompass any electronic, computing, and/or telecommunications device (or combination of devices) which is easily transported by a user and capable of wireless communication.

Base Station—The term "Base Station" has the full breadth of its ordinary meaning, and at least includes a wireless communication station installed at a fixed location and used to communicate as part of a wireless telephone system or radio system.

Processing Element—refers to various elements or combinations of elements. Processing elements include, for example, circuits such as an ASIC (Application Specific Integrated Circuit), portions or circuits of individual processor cores, entire processor cores, individual processors, programmable hardware devices such as a field programmable gate array (FPGA), and/or larger portions of systems that include multiple processors.

Channel—a medium used to convey information from a sender (transmitter) to a receiver. It should be noted that since characteristics of the term "channel" may differ according to different wireless protocols, the term "channel" as used herein may be considered as being used in a manner that is consistent with the standard of the type of device with reference to which the term is used. In some standards, channel widths may be variable (e.g., depending on device capability, band conditions, etc.). For example, LTE may support scalable channel bandwidths from 1.4 MHz to 20 MHz. In contrast, WLAN channels may be 22 MHz wide while Bluetooth channels may be 1 Mhz wide. Other protocols and standards may include different definitions of channels. Furthermore, some standards may define and use multiple types of channels, e.g., different channels for uplink or downlink and/or different channels for different uses such as data, control information, etc.

Band—The term "band" has the full breadth of its ordinary meaning, and at least includes a section of spectrum (e.g., radio frequency spectrum) in which channels are used or set aside for the same purpose.

Automatically—refers to an action or operation performed by a computer system (e.g., software executed by the computer system) or device (e.g., circuitry, programmable hardware elements, ASICs, etc.), without user input directly specifying or performing the action or operation. Thus the term "automatically" is in contrast to an operation being manually performed or specified by the user, where the user provides input to directly perform the operation. An automatic procedure may be initiated by input provided by the user, but the subsequent actions that are performed "automatically" are not specified by the user, i.e., are not performed "manually", where the user specifies each action to perform. For example, a user filling out an electronic form by selecting each field and providing input specifying information (e.g., by typing information, selecting check boxes, radio selections, etc.) is filling out the form manually, even though the computer system must update the form in response to the user actions. The form may be automatically filled out by the computer system where the computer system (e.g., software executing on the computer system) analyzes the fields of the form and fills in the form without any user input specifying the answers to the fields. As indicated above, the user may invoke the automatic filling of the form, but is not involved in the actual filling of the form (e.g., the user is not manually specifying answers to fields but rather they are being automatically completed). The present specification provides various examples of operations being automatically performed in response to actions the user has taken.

FIGS. **1** and **2**—Communication System

FIG. **1** illustrates an exemplary (and simplified) wireless communication system, according to some embodiments. It is noted that the system of FIG. **1** is merely one example of a possible system, and embodiments may be implemented in any of various systems, as desired.

As shown, the exemplary wireless communication system includes a base station **102**A, which communicates over a transmission medium with one or more user devices **106**A, **106**B, etc., through **106**N. Each of the user devices may be referred to herein as a "user equipment" (UE). Thus, the user devices **106** are referred to as UEs or UE devices.

The base station **102**A may be a base transceiver station (BTS) or cell site, and may include hardware that enables wireless communication with the UEs **106**A through **106**N. The base station **102**A may also be equipped to communicate with a network **100** (e.g., a core network of a cellular service provider, a telecommunication network such as a public switched telephone network (PSTN), and/or the Internet, among various possibilities). Thus, the base station **102**A may facilitate communication between the user devices and/or between the user devices and the network **100**.

The communication area (or coverage area) of the base station may be referred to as a "cell." The base station **102**A and the UEs **106** may be configured to communicate over the transmission medium using any of various radio access technologies (RATs), also referred to as wireless communication technologies, or telecommunication standards, such as GSM, UMTS (WCDMA, TD-SCDMA), LTE, LTE-Advanced (LTE-A), 3GPP2 CDMA2000 (e.g., 1×RTT, 1×EV-DO, HRPD, eHRPD), Wi-Fi, WiMAX etc.

Additionally, one or more access points (such as access point **104**) may be communicatively coupled to the network **100**. These may include Wi-Fi access points configured to support cellular network offloading and/or otherwise provide wireless communication services as part of the wireless communication system illustrated in FIG. **1**.

Base station **102**A and other similar base stations (such as base stations **102**B . . . **102**N) and/or access points (such as access point **104**) operating according to the same or a different wireless communication standard may thus be provided as a network of cells, which may provide continuous or nearly continuous overlapping service to UEs

106A-N and similar devices over a wide geographic area via one or more wireless communication standards.

Thus, while base station **102**A may act as a "serving cell" for UEs **106**A-N as illustrated in FIG. **1**, each UE **106** may also be capable of receiving signals from (and possibly within communication range of) one or more other cells (which might be provided by base stations **102**B-N and/or any other base stations) and/or wireless local area networks (WLANs), which may be referred to as "neighboring cells" or "neighboring WLANs" (e.g., as appropriate), and/or more generally as "neighbors". Such neighbors may also be capable of facilitating communication between user devices and/or between user devices and the network **100**. Such neighbors may include "macro" cells, "micro" cells, "pico" cells, "femto" cells, WLANs, and/or cells which provide any of various other granularities of service area size. For example, base stations **102**A-B illustrated in FIG. **1** might provide macro cells, base station **102**N might provide a micro cell, and access point **104** might be a Wi-Fi AP which provides a WLAN. Note also that in some instances, a UE (such as one of UEs **106**A-N) may be served by multiple neighboring cells (e.g., a serving set), for example using coordinated multipoint (CoMP) wireless communication. Other configurations are also possible.

Note that a UE **106** may be capable of communicating using multiple wireless communication standards. For example, a UE **106** might be configured to communicate using two or more of GSM, UMTS, CDMA2000, WiMAX, LTE, LTE-A, WLAN, Bluetooth, one or more global navigational satellite systems (GNSS, e.g., GPS or GLONASS), one and/or more mobile television broadcasting standards (e.g., ATSC-M/H or DVB-H), etc. Other combinations of wireless communication standards (including more than two wireless communication standards) are also possible.

Any or all of the network **100**, base stations **102**, access points **104**, and/or UEs **106** illustrated in FIG. **1** may be configured to implement or support implementation of part or all of the methods described herein, including, inter alia, the method of FIG. **5**.

FIG. **2** illustrates an exemplary (and simplified) system in which user equipment **106** (e.g., one of the devices **106**A through **106**N) is in communication with a base station **102** (e.g., one of the base stations **102**A through **102**N), according to some embodiments. The UE **106** may be a device with cellular communication capability, such as a mobile phone, a hand-held device, a computer or a tablet, or virtually any type of wireless device.

The UE **106** may include a processor that is configured to execute program instructions stored in memory. The UE **106** may perform any of the method embodiments described herein by executing such stored instructions. Alternatively, or in addition, the UE **106** may include a programmable hardware element such as an FPGA (field-programmable gate array) that is configured to perform any of the method embodiments described herein, or any portion of any of the method embodiments described herein.

In some embodiments, the UE **106** may be configured to communicate using any of multiple radio access technologies/wireless communication protocols. For example, the UE **106** may be configured to communicate using two or more of GSM, UMTS, CDMA2000, LTE, LTE-A, WLAN/Wi-Fi, or GNSS. Other combinations of wireless communication technologies are also possible.

The UE **106** may include one or more antennas for communicating using one or more wireless communication protocols or technologies. In one embodiment, the UE **106** might be configured to communicate using either of

CDMA2000 (1×RTT/1×EV-DO/HRPD/eHRPD) or LTE using a single shared radio and/or GSM or LTE using the single shared radio. The shared radio may couple to a single antenna, or may couple to multiple antennas (e.g., for MIMO) for performing wireless communications. In general, a radio may include any combination of a baseband processor, analog RF signal processing circuitry (e.g., including filters, mixers, oscillators, amplifiers, etc.), or digital processing circuitry (e.g., for digital modulation as well as other digital processing). Similarly, the radio may implement one or more receive and transmit chains using the aforementioned hardware. For example, the UE **106** may share one or more parts of a receive and/or transmit chain between multiple wireless communication technologies, such as those discussed above.

In some embodiments, the UE **106** may include separate transmit and/or receive chains (e.g., including separate RF and/or digital radio components) for each wireless communication protocol with which it is configured to communicate. As a further possibility, the UE **106** may include one or more radios that are shared between multiple wireless communication protocols and one or more radios that are used exclusively by a single wireless communication protocol. For example, the UE **106** might include a shared radio for communicating using either of LTE and 1×RTT (or LTE or GSM), and separate radios for communicating using each of Wi-Fi and Bluetooth. Other configurations are also possible.

FIG. **3**—Exemplary Block Diagram of a UE

FIG. **3** illustrates an exemplary block diagram of a UE **106**, according to some embodiments. As shown, the UE **106** may include a system on chip (SOC) **300**, which may include portions for various purposes. For example, as shown, the SOC **300** may include processor(s) **302**, which may execute program instructions for the UE **106**, and display circuitry **304**, which may perform graphics processing and provide display signals to the display **360**. The processor(s) **302** may also be coupled to memory management unit (MMU) **340**, which may be configured to receive addresses from the processor(s) **302** and translate those addresses to locations in memory (e.g., memory **306**, read only memory (ROM) **350**, NAND flash memory **310**) and/or to other circuits or devices, such as the display circuitry **304**, wireless communication circuitry **330**, connector I/F **320**, and/or display **360**. The MMU **340** may be configured to perform memory protection and page table translation or set up. In some embodiments, the MMU **340** may be included as a portion of the processor(s) **302**.

As shown, the SOC **300** may be coupled to various other circuits of the UE **106**. For example, the UE **106** may include various types of memory (e.g., including NAND flash **310**), a connector interface **320** (e.g., for coupling to a computer system, dock, charging station, etc.), the display **360**, and wireless communication circuitry (e.g., radio) **330** (e.g., for LTE, Wi-Fi, GPS, etc.).

The UE device **106** may include at least one antenna, and in some embodiments multiple antennas, for performing wireless communication with base stations and/or other devices. For example, the UE device **106** may use antenna(s) **335** to perform the wireless communication. As noted above, the UE **106** may be configured to communicate wirelessly using multiple wireless communication standards in some embodiments.

As described further subsequently herein, the UE **106** may include hardware and software components for implementing part or all of the methods described herein. The processor(s) **302** of the UE device **106** may be configured to implement part or all of the methods described herein, e.g., by executing program instructions stored on a memory medium (e.g., a non-transitory computer-readable memory medium). In other embodiments, processor(s) **302** may be configured as a programmable hardware element, such as an FPGA (Field Programmable Gate Array), or as an ASIC (Application Specific Integrated Circuit). Alternatively (or in addition) the processor(s) **302** of the UE device **106**, in conjunction with one or more of the other components **300**, **304**, **306**, **310**, **320**, **330**, **335**, **340**, **350**, **360** may be configured to implement part or all of the features described herein.

FIG. **4**—Exemplary Block Diagram of a Base Station

FIG. **4** illustrates an exemplary block diagram of a base station **102**, according to some embodiments. It is noted that the base station of FIG. **4** is merely one example of a possible base station. As shown, the base station **102** may include processor(s) **404**, which may execute program instructions for the base station **102**. The processor(s) **404** may also be coupled to memory management unit (MMU) **440**, which may be configured to receive addresses from the processor(s) **404** and translate those addresses to locations in memory (e.g., memory **460** and read only memory (ROM) **450**) or to other circuits or devices.

The base station **102** may include at least one network port **470**. The network port **470** may be configured to couple to a telephone network and provide a plurality of devices, such as UE devices **106**, access to the telephone network as described above in relation to FIGS. **1** and **2**.

The network port **470** (or an additional network port) may also or alternatively be configured to couple to a cellular network, e.g., a core network of a cellular service provider. The core network may provide mobility related services and/or other services to a plurality of devices, such as UE devices **106**. In some cases, the network port **470** may couple to a telephone network via the core network, and/or the core network may provide a telephone network (e.g., among other UE devices serviced by the cellular service provider).

The base station **102** may include at least one antenna **434**, and possibly multiple antennas. The antenna(s) **434** may be configured to operate as a wireless transceiver and may be further configured to communicate with UE devices **106** via wireless communication circuitry **430**. The antenna(s) **434** communicates with the wireless communication circuitry **430** via communication chain **432**. Communication chain **432** may be a receive chain, a transmit chain or both. In some implementations, communication chain **432** may include multiple receive chains, multiple transmit chains, or both. The wireless communication circuitry **430** may be configured to communicate via various wireless telecommunication standards, including, but not limited to, LTE, LTE-A, UMTS, CDMA2000, Wi-Fi, etc.

The BS **102** may be configured to communicate wirelessly using multiple wireless communication standards. In some instances, the base station **102** may include multiple radios, which may enable the base station **102** to communicate according to multiple wireless communication technologies. For example, as one possibility, the base station **102** may include an LTE radio for performing communication according to LTE as well as a Wi-Fi radio for performing communication according to Wi-Fi. In such a case, the base station **102** may be capable of operating as either or both of an LTE base station and a Wi-Fi access point. As another possibility, the base station **102** may include a multi-mode radio, which is capable of performing communications according to any of multiple wireless communication technologies (e.g., LTE and Wi-Fi).

The BS **102** may include hardware and software components for implementing part or all of the methods described herein. The processor(s) **404** of the base station **102** may be configured to implement part or all of the methods described herein, e.g., by executing program instructions stored on a memory medium (e.g., a non-transitory computer-readable memory medium). Alternatively, the processor(s) **404** may be configured as a programmable hardware element, such as an FPGA (Field Programmable Gate Array), or as an ASIC (Application Specific Integrated Circuit), or a combination thereof. Alternatively (or in addition) the processor(s) **404** of the BS **102**, in conjunction with one or more of the other components **430**, **432**, **434**, **440**, **450**, **460**, **470** may be configured to implement part or all of the features described herein.

FIG. **5**—Communication Flow Diagram

FIG. **5** is a communication/signal flow diagram illustrating an example method for managing cellular network elements that operate in unlicensed frequency bands, according to some embodiments. Aspects of the method of FIG. **5** may be implemented by a cellular base station or Wi-Fi access point, or more generally in conjunction with any of the computer systems or devices shown in the above Figures, among other devices, as desired.

In various embodiments, some of the elements of the method shown may be performed concurrently, in a different order than shown, or may be omitted. Additional elements may also be performed as desired. As shown, the method may operate as follows.

In **502**, a "first base station" (e.g., BS **102**A) may receive an operation and management (OAM) policy. The OAM policy may be received from an OAM policy manager that manages a first wireless service provider's network. The OAM policy manager may itself be implemented by the first base station or may be implemented as part of a separate network element in the first wireless service provider's network.

The OAM policy may include any of various OAM policy information, such as parameters and/or instructions according to which the first base station may operate, and/or parameters and/or instructions according to which to configure other network elements to operate.

In **504**, the first base station may configure a network element in the first wireless service provider's network that operates in an unlicensed frequency band according to the OAM policy. The network element may be any of various network elements, such as a second base station (e.g., BS **102**N) or an access point (e.g., AP **104**). Configuring the network element may include providing, from the OAM policy, policy and/or parameter information that relates to the network element. For example, configuring the network element may include providing an activation or deactivation indication or schedule, which may indicate times at which to operate and/or times at which not to operate. As another example, configuring the network element may include providing an indication of a frequency or frequency range (e.g., in the unlicensed frequency band) on which to operate.

The OAM policy information may be configured in particular to manage potential interference in the unlicensed frequency band. Because of the unlicensed aspect of an unlicensed frequency band, it may be possible for multiple wireless communication technologies to be used simultaneously in a manner that results in interference and degraded communication characteristics for one or more of the those interfering wireless communication technologies. It may furthermore be possible in such a band for multiple network operators to attempt to use the same wireless communication technology in an uncoordinated manner, which also or alternatively results in interference and degraded communication characteristics for their networks. OAM policy information, such as scheduling of time-sharing and/or selecting operating frequencies in a manner coordinated to avoid or reduce interference between network elements of the same and/or different networks operating according to the same and/or different wireless communication technologies, may thus function to manage/control such potential interference in unlicensed frequency bands.

In **506**, the network element (e.g., BS **102**N or AP **104**) may operate in the unlicensed frequency band according to the OAM policy. This may include not operating (e.g., deactivating or turning itself off) during certain scheduled times and operating (e.g., activating or turning itself on) during certain scheduled times, and/or operating on a specific frequency or frequency range indicated in the OAM policy.

Note additionally that, at least in some instances, OAM policy may be informed by/based on information regarding current operational characteristics of network elements that may be provided by the first base station. For example, the first base station may be capable of automatically maintaining information concerning neighbors of the first base station, and may provide such information to the OAM entity. The information maintained by the first base station may include identification information, operation frequency information, interference information, and/or any of various other neighbor information for neighboring cells and/or neighboring WLANs.

Such information may be maintained by the first base station as part of communications with user devices attached to the first base station. For example, user devices attached to the first base station may at times detect and/or perform measurements on neighboring cells, Wi-Fi networks, and/or any of various other possible network elements, and provide some or all of the information collected as part of such detection and/or measurements to the first base station. As another (additional or alternative) possibility, network elements coupled to the first base station may provide information regarding their own operation, and/or may collect information (from user devices attached to those network elements) regarding their neighboring cells, Wi-Fi networks, and/or any of various other possible network elements. As a still further possibility, information (e.g., regarding operating characteristics of network elements belonging to different networks) may be received by the first base station from one or more network nodes of different networks, e.g., by way of an inter-network communication interface. Such information may be used to determine policy decisions, for example by determining if any network elements are interfering or have the potential to interfere with each other and selecting time sharing policies and/or frequency assignments to mitigate or avoid interference between those network elements.

FIGS. **6-19**—Additional Information

FIGS. **6-19** and the information provided herein below in conjunction therewith are provided by way of example of various considerations and details relating to possible systems in which the method of FIG. **5** and/or other aspects of this disclosure may be implemented, and are not intended to be limiting to the disclosure as a whole. Numerous variations and alternatives to the details provided herein below are possible and should be considered within the scope of the disclosure.

FIG. **6** illustrates an exemplary set of entities with which an OAM entity of a communication network may have interfaces, in an exemplary 3GPP deployment, such as according to 3GPP TS 32.102, according to some embodiments. As shown, the entities may include various basic entities **610**, potentially including those in user equipment (UE) **612**, access network (AN) **614**, and core network (CN) **616** realms, as well as service specific entities **626** (e.g., depending on the specific services provided as part of the communication network). The CN entities **616** may further be distinguished as belonging to circuit switched (CS) **618**, common packet switched (PS)/CS **620**, general packet radio service (GPRS) PS **622**, or evolved packet core (EPC) PS **624** domains. Note that RAN3 may define what RAN parameters (high level principles) transfer to OAM. The OAM may push parameters to the RAN.

FIG. **7** illustrates exemplary possible OAM interfaces within and between networks, according to some embodiments. The network elements (NEs) illustrated in FIG. **7** may be representative of macro base stations (e.g., macro eNodeBs or MeNBs), small cell base stations (e.g., small eNodeBs or SeNBs), Wi-Fi access points, and/or any of various other possible network elements. As shown, interface **1** may be between NEs and the element manager (EM) of a particular public land mobile network (PLMN) organization or wireless service provider. Interface **2** may be between EMs and the network manager (NM) of the PLMN. Note that in certain cases the EM functionality may reside in the NE, in which case this interface may be directly from NE to NM. These management interfaces may be given the reference name Itf-N. Interface **3** may be between enterprise systems and NMs of a given PLMN organization. Interface **4** may be between NMs of a given PLMN organization, and interface **4***a* may be between the Domain Managers (DMs) of a given PLMN organization (as shown, in some instances interface **4***a* may also be referred to as Itf-P2P). Interface **5** may be between enterprise systems of different PLMN organizations and/or between NMs of different PLMN organizations, and interface **5***a* may be between the DMs of different PLMN Organizations. Interface **6** may be between NEs of a given PLMN organization.

FIG. **8** illustrates exemplary self-organizing network (SON) functionality, which may be implemented by a base station (e.g., eNB) operating in a PLMN, according to some embodiments. As shown, the SON functionality may include various states, such as self-configuration **800** and self-optimization **850**. A goal of implementing SON functionality may include reducing the operator configuration load, for example, to reduce configuration work on the eNB for neighbor relations and to reduce OAM interaction with the eNB.

In self-configuration **800**, the OAM entity may only be involved in providing remote eNB IP configuration, e.g., for establishing a connection between the eNB and the EPC. For example, as shown, self-configuration may include basic setup **810** of the eNB and initial radio configuration **820** of the eNB. Basic setup **810** may include configuration of IP address and detection of OAM **812**, authentication of the eNB and the network **814**, association of the eNB with a gateway **816**, and downloading of eNB software and operational parameters to the eNB **818**. Initial radio configuration **820** may include neighbor list configuration **822** and coverage and capacity related parameter configuration **824**. Note that other basic setup and initial radio configuration arrangements are also possible, potentially including any of a variety of other possible alternative or additional steps (as indicated by the continuing dashed lines illustrated in FIG. **8** following steps **818** and **824**), e.g., according to various implementations.

In Self-optimization **850**, the OAM may be involved in providing on/off policy/indications, e.g., for energy saving. For example, as shown, self optimization **850** may include optimization and adaptation **860**, which may further include neighbor list optimization **862** and coverage and capacity control **864**. Note that other optimization and adaptation arrangements are also possible, potentially including any of a variety of other possible alternative or additional steps (as indicated by the continuing dashed lines illustrated in FIG. **8** following step **864**), e.g., according to various implementations.

FIG. **9** illustrates exemplary automatic neighbor relations (ANR) functionality (according to some embodiments), which may be one example of a SON behavior which may be implemented by a base station in a PLMN; ANR may reduce the operator configuration work load of maintaining a neighbor relations table (NRT) at each base station, at least in some instances.

As shown, the ANR function **910** may maintain a NRT **920** for the base station **900** at which the ANR function **910** is implemented. The NRT **920** may include various policy information relating to neighbors of the base station, such as whether the neighbor should not be removed from the NRT **920**, whether the neighbor should be used for handover reasons, and/or whether the base station should use an X2 interface in order to initiate procedures (such as handovers, among various other possible procedures) with the base station parenting the neighbor.

The ANR **910** may populate and update the NRT **920** based on information received from the base station's radio resource control (RRC) **930** functionality, which may include updates (e.g., measurement reports) received from user devices attached to a cell provided by the base station **900**. The ANR function **910** also may, e.g., occasionally, provide neighbor relations reports to the OAM entity **950**, and/or receive updates or additions to the NRT **920** from the OAM **950**. Additionally, in some instances, the ANR **910** may remove neighbors from the NRT **920** based on internal information (e.g., if not forbidden to do so according to the NRT **920**).

FIG. **10** illustrates an exemplary scenario in which an ANR function of an eNB may obtain neighbor information from a user device. As shown, an eNB **1010** (e.g., providing cell A illustrated in FIG. **10**) may request a neighbor report from a user device **1020**. The user device **1020** may determine the physical layer cell identifier (Phy-CID) and signal level of a second base station **1030** (e.g., providing cell B illustrated in FIG. **10**) and provide this information to the eNB **1010**. The eNB **1010** may further request the global cell identifier (global-CID) of the second base station **1030**, which may then be obtained and provided back to the eNB **1010** by the user device **1020**. Note that some or all of this behavior may be performed as part of normal service provision (e.g., for determining serving cell, handover candidates, etc.) for the user device **1020** illustrated in FIG. **10**, e.g., in addition to/in conjunction with its utility in providing information to the ANR to maintain an updated NRT.

As an energy saving feature, it may be the case that a network element may be switched on and off by the network operator, the network OAM entity, and/or autonomously by the network element itself. For example, depending on long-term (e.g., averaged) loading considerations, it might be determined that a particular cell is superfluous, and the base station providing the cell may accordingly be switched off for a length of time. When dormant or switched off, the base station may not send any signaling, and may generally conserve power.

For a base station to internally decide to switch on/off, the base station may send a base station configuration update to neighboring base stations; for example, an eNB in a 3GPP deployment might send an eNB configuration update such as described in TS 36.423 section 9.1.2.9 using the X2 interface with neighboring eNBs in an intra-RAT scenario. A related S1 message may be sent to base stations operating according to other RATs in an inter-RAT scenario.

If OAM is involved in such a decision, the OAM may decide which cell enters or leaves the dormant mode, and intra-RAT and inter-RAT neighbors of the cell may be informed that the selected cell is entering or leaving the dormant mode by the OAM.

While some cellular systems may utilize only licensed frequency bands, in some instances a network operator may deploy cells (e.g., small cells) that operate in unlicensed frequency bands, such as industrial-scientific-medical (ISM) frequency bands. Such cells may be referred to as LTE-U cells. In order for such LTE-U cells to co-exist with Wi-Fi communications in such bands, an on/off mechanism may be provided for LTE-U deployments. The mechanism may help prevent LTE-U cells from blocking Wi-Fi devices from accessing channels, which may be important since LTE transmission timelines may typically be longer than Wi-Fi transmission timelines.

While LTE Releases 11/12 include an energy saving on/off mechanism for small cells, the mechanism is relatively static (e.g., not sufficiently dynamic to adapt to interference or short-term load based triggers) and relatively slow. Accordingly, an on/off mechanism that may be more suitable for small cells operating in unlicensed frequency bands, such as one that considers interference levels, loading conditions, and/or coexistence issues, may be used in such scenarios.

In particular, a centralized OAM entity for network planning and resource sharing may be used between macro eNBs, LTE-U small cells, and Wi-Fi APs managed by operators. LTE-U/Wi-Fi channel frequencies and interference measurements may fall within the scope of OAM parameters. Additionally, OAM policy may encompass an on/off trigger mechanism by macro eNBs for LTE-U cells and Wi-Fi APs. Changing channel frequency deployment of LTE-U cells and Wi-Fi APs based on interference measurement(s) (e.g., frequency hopping mechanism) may fall within the scope of the OAM policy.

An OAM architecture for such wireless communication systems encompassing unlicensed frequency bands may include interfaces between macro eNBs and small cells (and Wi-Fi APs) for implementing the OAM policy. Furthermore, SON report mechanisms may be extended, e.g., in order to improve OAM policy updates with respect to network elements operating in unlicensed frequency bands. In addition, an interface for inter-operator OAM coordination may be provided, e.g., in order to support inter-operator coordination in unlicensed frequency bands.

FIG. **11** illustrates an example of such an OAM architecture for managing and supporting network elements operating in unlicensed frequency bands. As shown, each of multiple network operators (e.g., OAM operator **1100** and OAM operator **1150**) may have various network elements deployed in a particular region. Each network operator's OAM entity may include an OAM policy manager (e.g., policy managers **1110**, **1160**), which may be provisioned to macro eNBs (e.g., MeNBs **1120**, **1122**, **1170**) of that network via interface **1**. The macro eNBs may in turn interface with small cells (e.g., Scells **1130**, **1132**, **1134**, **1180**, **1182**), for example using the X2 interface, and Wi-Fi APs (e.g., Wi-Fi APs **1140**, **1190**, **1192**), for example using an X3 interface described further subsequently herein. Additionally, an inter-operator interface **5***a* may be provided, on which each OAM's on/off policy and information such as the frequency channels of Wi-Fi APs and LTE-U cells may be communicated.

Thus, the OAM may provision the various base stations and APs with on/off policy and parameters. The macro eNB(s) may measure all relevant parameters and apply the policy. This may include triggering LTE-U cells and Wi-Fi APs to be on or off, and/or to operate in different frequency channels (frequency hopping). Additionally, UEs may report SON measurements to the macro eNBs and the small cells, which may in turn be transferred to the OAM. The OAM may from time to time receive these and any other measurements and parameters and update the OAM policy as desired. Note that the role of the OAM policy manager with respect to the network elements, according to some embodiments, is also illustrated in FIG. **12**.

FIGS. **13** and **14** illustrate communication flow between a macro eNB, a small eNB, a Wi-Fi AP, and an OAM entity for implementing on/off policy and operation frequency changes respectively.

As shown in FIG. **13**, in **1310** an OAM **1308** may provide initial policy provisioning to a MeNB **1302**. Based on the policy, the MeNB **1302** may decide, and provide indications of, which SeNBs and which APs to trigger on and/or off, possibly including timer and/or more detailed scheduling information such as a daily or weekly operation schedule. For example, in **1320**, the MeNB **1302** may indicate to SeNB **1304** to activate; in **1330**, the MeNB **1302** may indicate to AP **1306** to activate; and in **1340**, the MeNB **1302** may provide a policy update trigger back to the OAM **1308**. Similarly, in **1350**, the MeNB **1302** might indicate to the SeNB **1304** to deactivate; in **1360**, the MeNB **1302** might indicate to the AP **1306** to deactivate; and in **1370**, the MeNB **1302** might provide a further policy update back to the OAM **1308**.

As shown in FIG. **14**, in **1410** an OAM **1408** may provide initial policy provisioning to a MeNB **1402**. Based on the policy, the MeNB **1402** may decide, and provide indications of, frequency channels on which SeNB **1404** and AP **1406** are to operate. For example, in **1420**, the MeNB **1402** may indicate to the SeNB **1404** on which frequency to operate; in **1430**, the MeNB **1402** may indicate to the AP **1406** on which frequency to operate; and in **1440**, the MeNB **1402** may provide a policy update trigger back to the OAM **1408**.

Note that additionally (e.g., on an occasional, possibly periodic basis), a MeNB may obtain information regarding operational frequency, load, and/or interference for some or all SeNBs and APs under the management of the MeNB, and provide such information to the OAM when a policy updated is triggered (e.g., in one or more of steps **1340**, **1370**, and/or **1440** of FIGS. **13**-**14**).

FIGS. **15**-**17** illustrate aspects of an X3 interface, which may be used between eNBs and Wi-Fi APs. The X3 interface may utilize the same protocol stack as X2, including both user plane protocol stack **1510** and control plane protocol stack **1520**, such as illustrated in FIG. **15**. However, in contrast with X2, certain additional (new) messages may be defined and used in X3 relative to X2. For example, according to some embodiments, X3 may include messages for requesting activation, deactivation, and/or change of operation frequency.

FIG. **16** is a communication flow diagram more particularly illustrating exemplary X3 messages for requesting activation and/or deactivation of a Wi-Fi AP, according to some embodiments. As shown, in **1610** a MeNB **1602** may provide a message requesting activation ("ON") of a Wi-Fi AP **1606** using the X3 interface. In some instances, the message may include a timer, e.g., for indicating a length of time for which to activate. In **1620**, the MeNB **1602** may provide a message requesting deactivation ("OFF") of the Wi-Fi AP **1606** using the X3 interface, which may similarly include a timer for deactivation length, at least in some instances.

FIG. **17** is a communication flow diagram more particularly illustrating an exemplary X3 message for requesting that a Wi-Fi AP operate on a different frequency channel. As shown, in **1710** a MeNB **1702** may provide a message using the X3 interface requesting that a Wi-Fi AP **1706** operate on a different frequency channel. In some embodiments, the request may specify a new channel (e.g., "f1") on which to operate.

As previously noted, the OAM policy provided by the OAM entity of a network operator's network to the network elements (such as MeNBs) of the network may include policy and parameter information for managing network elements operating in unlicensed frequency bands, such as interference level thresholds and/or timing, timers for on/off of specific network elements, possible LTE-U and Wi-Fi channels, etc. As an example, the following represents one possible XML entry format which may be used to communicate such information:

```
<element name="LTEUCoordination">
  <complexType>
    <sequence>
      <element ref="cd:MeasurementQuantity-LTEU" minOccurs="0"/>
      <element name="MeasurementQuantity-AP" minOccurs="0"/>
      <element name="TimerON" type="unsignedInt" minOccurs="0"/>
      <element name="TimerOFF" type="unsignedInt" minOccurs="0"/>
      <element name="FreqChannelAP" type="unsignedInt" minOccurs=
      "0"/>
      <element name="FreqChannelLTEU" type="unsignedInt"
      minOccurs="0"/>
      <element name="ThresholdInterferenceLTEU" type="integer"
      minOccurs="0"/>
      <element name="ThresholdInterferenceAP" type="integer"
      minOccurs="0"/>
    </sequence>
  </complexType>
</element>
```

FIG. **18** illustrates exemplary self-organizing network functionality, which may be implemented by a base station (e.g., eNB) operating in a PLMN, which may be similar to the self-configuration and self-optimization functionality illustrated in FIG. **8**, but with certain aspects modified and/or added to support management of network elements operating in unlicensed frequency bands. In particular, in addition to basic setup **1810** and the neighbor list configuration **1822** and coverage/capacity related parameter configuration **1824** steps of initial radio configuration **1820**, as shown in bold, a step of OAM policy provisioning (e.g., of NEs operating in unlicensed frequency bands) and updating the NRT based on policy updates **1826** may be included in the self-configuration phase **1800**, according to some embodiments. Additionally (or alternatively), in the self-optimization phase **1850**, the neighbor list configuration **1862** and coverage, capacity, and interference control **1864** steps of optimization/adaptation **1860** may be modified in conjunction with interference control and/or coordination and/or other possible policy decisions, according to some embodiments. As similarly described in relation to FIG. **8**, the SON functionality of FIG. **18** may alternatively or additionally include any of a variety of other possible alternative or additional steps (as indicated by the continuing dashed lines illustrated in FIG. **18** following steps **1826** and **1864**), e.g., according to various implementations.

FIG. **19** illustrates exemplary ANR functionality, which may be one example of a SON behavior that may be implemented by a base station in a PLMN. The ANR **1910** functionality illustrated in FIG. **19** may be similar to that illustrated in FIG. **9**, but with aspects modified to support management of network elements operating in unlicensed frequency bands. In particular, according to some embodiments, as shown in bold, a 'no X3' column **1922** may be added to the new NRT **1920** to allow the OAM policy manager **1950** to indicate whether the base station **1900** should use the X3 interface in order to initiate procedures (such as handovers, among various other possible procedures) with a Wi-Fi AP parenting a neighbor.

Additionally (or alternatively), in some embodiments, neighbor Wi-Fi information **1932** may be collected from the RRC **1930**, for example in measurement reports provided from the RRC **1930** to a neighbor detection function of the ANR **1910**. The neighbor Wi-Fi information may potentially include some or all of SSIDs, frequency channels, and interference levels of neighboring Wi-Fi networks detected by the RRC **1930** (e.g., directly or indirectly by way of one or more UEs served by base station **1900**). Such neighbor Wi-Fi information may also be provided from a NRT management function of the ANR **1910** to the OAM **1950**, for example as part of neighbor relations reports **1952**. Additionally (or alternatively), policy updates **1954** for neighbor Wi-Fi APs managed by the base station **1900** may in some instances be received by the NRT management function of the ANR **1910** from the OAM **1950**.

In the following further exemplary embodiments are provided.

One set of embodiments may include a method for managing a wireless communication system, comprising: receiving operation and management (OAM) policy and parameter information at a first base station, wherein the first base station is a network element in a first wireless service provider's network, wherein the OAM policy is received from an OAM entity of the first wireless service provider's network; configuring, by the first base station, at least a second base station according to the policy and parameter information, wherein the second base station is a network element in a first wireless service provider's network, wherein the second base station is configured to wirelessly communicate on an unlicensed frequency band.

According to some embodiments, configuring the second base station comprises providing an activation or deactivation indication.

According to some embodiments, configuring the second base station comprises providing an indication of a frequency on which to operate.

According to some embodiments, the first base station is a macro eNodeB configured to provide wireless communication services via LTE, wherein the second base station is one or more of: a small cell configured to provide wireless communication services in the unlicensed frequency band via LTE; or an access point configured to provide wireless communication services in the unlicensed frequency band via Wi-Fi.

According to some embodiments, the method further comprises: receiving, at the first base station, neighbor information from one or more user devices, wherein the neighbor information comprises, for one or more neighbor base stations of the first base station including the second base station, one or more of: identification information; operation frequency information; or interference information; and providing, by the first base station, the neighbor information to the OAM entity of the first wireless service provider's network.

According to some embodiments, the OAM policy and parameters comprises interference control information configured for managing interference in unlicensed frequency bands, wherein the interference control information is based at least in part on inter-operator coordination information.

An additional exemplary embodiment may include a cellular base station (BS), comprising: a radio; and a processing element operably coupled to the radio; wherein the BS is configured to implement any or all parts of any of the methods of the preceding examples.

A further set of exemplary embodiments may include a method for operating an LTE small-cell base station (BS) or Wi-Fi access point (AP), wherein the BS or AP is configured to operate in an unlicensed frequency band as a network element in a first wireless service provider's network, the method comprising: receiving configuration information from a macro base station, wherein the macro base station is a network element in the first wireless service provider's network, wherein the configuration information is for configuring the BS or AP according to an interference management policy for managing interference in the unlicensed frequency band.

An additional exemplary embodiment may include a LTE small-cell base station (BS) or Wi-Fi access point (AP), comprising: a radio; and a processing element operably coupled to the radio; wherein the LTE small-cell base station (BS) or Wi-Fi access point (AP) is configured to implement any or all parts of the method of the preceding example.

A further exemplary set of embodiments may include a non-transitory computer accessible memory medium comprising program instructions which, when executed at a device, cause the device to implement any or all parts of any of the methods of the preceding examples.

A still further exemplary set of embodiments may include a computer program comprising instructions for performing any or all parts of any of the methods of the preceding examples.

Yet another exemplary set of embodiments may include an apparatus comprising means for performing any or all of the method elements of any of the preceding examples.

Embodiments of the present disclosure may be realized in any of various forms. For example some embodiments may be realized as a computer-implemented method, a computer-readable memory medium, or a computer system. Other embodiments may be realized using one or more custom-designed hardware devices such as ASICs. Still other embodiments may be realized using one or more programmable hardware elements such as FPGAs.

In some embodiments, a non-transitory computer-readable memory medium may be configured so that it stores program instructions and/or data, where the program instructions, if executed by a computer system, cause the computer system to perform a method, e.g., any of a method embodiments described herein, or, any combination of the method embodiments described herein, or, any subset of any of the method embodiments described herein, or, any combination of such subsets.

In some embodiments, a device (e.g., a UE **106**) may be configured to include a processor (or a set of processors) and a memory medium, where the memory medium stores program instructions, where the processor is configured to read and execute the program instructions from the memory medium, where the program instructions are executable to implement any of the various method embodiments described herein (or, any combination of the method embodiments described herein, or, any subset of any of the method embodiments described herein, or, any combination of such subsets). The device may be realized in any of various forms.

Although the embodiments above have been described in considerable detail, numerous variations and modifications will become apparent to those skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications.

What is claimed is:

1. A method for managing a wireless communication system, comprising:

receiving operation and management (OAM) policy information at a first base station, wherein the first base station is a network element in a first wireless service provider's network, wherein the OAM policy information is received from an OAM entity of the first wireless service provider's network;

providing to a second base station, by the first base station, information for configuring the second base station according to the OAM policy information, wherein the information for configuring the second base station indicates scheduled operational and non-operational times for the second base station, wherein the second base station is a network element in a first wireless service provider's network, wherein the second base station is configured to wirelessly communicate on an unlicensed frequency band.

2. The method of claim **1**,

wherein the information for configuring the second base station further comprises an indication of a frequency on which to operate.

3. The method of claim **1**,

wherein the first base station is a macro eNodeB configured to provide wireless communication services via LTE,

wherein the second base station comprises one or more of:

a small cell configured to provide wireless communication services in the unlicensed frequency band via LTE; or

an access point configured to provide wireless communication services in the unlicensed frequency band via Wi-Fi.

4. The method of claim **1**, the method further comprising:

receiving, at the first base station, neighbor information from one or more user devices, wherein the neighbor information comprises, for one or more neighbor base stations of the first base station including the second base station, one or more of:

identification information;

operation frequency information; or

interference information;

providing, by the first base station, the neighbor information to the OAM entity of the first wireless service provider's network.

5. The method of claim **1**,

wherein the OAM policy information comprises interference control information configured for managing interference in unlicensed frequency bands, wherein the interference control information is based at least in part on inter-operator coordination information.

6. A cellular base station (BS), comprising:

a radio; and

an processing element operably coupled to the radio;

wherein the radio and the processing element are configured to:

receive operation and management (OAM) policy information, wherein the OAM policy information comprises information for configuring a network element operating in an unlicensed frequency band; and

provide, according to the OAM policy, a first network element with one or more parameters for operating in an unlicensed frequency band, wherein the one or more parameters comprise a schedule for operating in the unlicensed frequency band.

7. The BS of claim 6,

wherein the OAM policy information comprises information configured to coordination operation of the first network element with one or more other network elements operating in the unlicensed frequency band.

8. The BS of claim 7,

wherein at least a subset of the one or more other network elements are deployed as part of a different network than the first network element.

9. The BS of claim 6,

wherein the one or more parameters further comprise one or more operating frequencies in the unlicensed frequency band.

10. A method for operating a network element, the method comprising:

by a first network element in a first wireless service provider's network:

receiving, from a base station, configuration information for configuring the first network element according to an interference management policy for managing interference in an unlicensed frequency band, wherein the configuration information indicates scheduled operational and non-operational times for the first network element, wherein the base station comprises a network element in the first wireless service provider's network; and

operating according to the configuration information to provide wireless service to one or more user devices in the first wireless service provider's network, wherein operating according to the configuration information comprises activating and deactivating according to the scheduled operational and non-operational times.

11. The method of claim 10, wherein the configuration information further indicates one or more operating frequencies in the unlicensed frequency band, wherein operating according to the configuration information further comprises:

providing wireless service at the one or more indicated operating frequencies during operational times.

12. The method of claim 10, wherein the configuration information further comprises information regarding one or more network elements neighboring the first network element, wherein the method further comprises:

coordinating operation of the first network element in the unlicensed frequency band to reduce interference between the first network element and the one or more network elements neighboring the first network element based at least in part on the information regarding the one or more network elements neighboring the first network element.

13. The method of claim 12,

wherein the one or more network elements neighboring the first network element comprise one or more network elements in a different network than the first network element and/or one or more network elements operating according to a different wireless communication technology than the first network element.

14. The method of claim 10, the method further comprising:

receiving information regarding one or more network elements neighboring the first network element from the one or more user devices in the first wireless service provider's network; and

providing information regarding the one or more network elements neighboring the first network element to the base station, wherein the provided information regarding the one or more network elements neighboring the first network element is usable for updating an operation and management policy for the first wireless service provider's network.

15. The method of claim 10, the method further comprising:

receiving updated configuration information from the base station, wherein the updated configuration information modifies one or more operating parameters for the first network element; and

operating according to the updated configuration information to provide wireless service to one or more user devices in the first wireless service provider's network.

16. The method of claim 10,

wherein the first network element comprises an LTE small-cell base station (BS).

17. The method of claim 10,

wherein the first network element comprises a Wi-Fi access point (AP).

* * * * *